U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

# EXPERIMENTS ON THE EFFECT OF MUSCULAR WORK UPON THE DIGESTIBILITY OF FOOD AND THE METABOLISM OF NITROGEN,

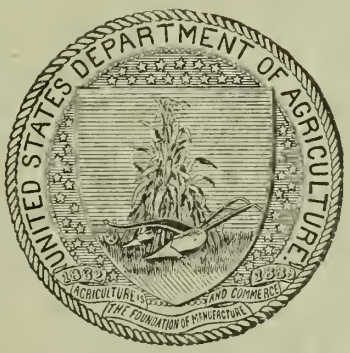
CONDUCTED AT THE

## UNIVERSITY OF TENNESSEE,

## 1897 to 1899.

BY

CHAS. E. WAIT, PH. D., F. C. S.,
*Professor of Chemistry at the University of Tennessee.*

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# LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
*Washington, D. C., September 29, 1900.*

Sir: I have the honor to transmit herewith a report on experiments on the effect of muscular work upon the digestibility of food and the metabolism of nitrogen conducted at the University of Tennessee, 1897–1899, by Charles E. Wait, professor of chemistry, under the immediate supervision of Prof. W. O. Atwater, special agent in charge of nutrition investigations, in accordance with instructions given by the Director of this Office. In carrying on these investigations Professor Wait was assisted by C. O. Hill, C. A. Mooers, W. H. Gildersleeve, and W. K. Hunter, all officially connected with the department of chemistry of the University of Tennessee.

Numerous dietary studies have been made in this and other countries in which the effect of muscular work was considered. There is, however, much less information available on the effects of muscular work upon digestibility and upon the metabolism of nitrogen. These topics are matters of great practical as well as scientific interest, and it is believed the present investigation is a valuable contribution to the subject.

The report is therefore submitted with the recommendation that it be published as Bulletin No. 89 of this Office.

Respectfully,

A. C. True,
*Director.*

Hon. James Wilson,
*Secretary of Agriculture.*

# CONTENTS.

# EFFECT OF MUSCULAR WORK UPON DIGESTION AND METABOLISM.

## INTRODUCTION.

The food requirements of the body under different conditions of muscular activity, the effect of muscular work upon digestibility, and the source of muscular power are subjects of no little interest and importance.[1] Little attention has apparently been paid to the second problem. A considerable amount of experimental investigation has been expended upon the other two. These subjects, perhaps, can be most satisfactorily studied by means of experiments with the respiration calorimeter, since with this apparatus the income and outgo of both matter and energy can be accurately determined. A number of such experiments have been made and the information thus accumulated is not inconsiderable. Much time and labor, however, are required to prosecute such extended inquiries. Considerable data of value can be obtained, it is believed, by a study of the digestibility of the diet and the income and outgo of nitrogen under conditions of varying muscular activity. A series of such investigations is reported in the following pages. The work is being continued along the same lines at the present time, and this report is intended more as a means of putting on record the data thus far accumulated than for the purpose of discussing these results at any great length.

## NATURE AND PLAN OF INVESTIGATIONS.

The investigations described may be considered as a continuation of those previously reported regarding the digestibility of the nutrients of a mixed diet.[2] They include 16 experiments, each, with one excep-

[1] The literature of the subject of food in relation to muscular work is large. Extended compilations and summaries of experiments bearing on different phases of the subject are given in U. S. Dept. Agr., Office of Experiment Stations Bul. 45. Dietary studies, digestion and metabolism experiments along these lines, conducted as part of the nutrition investigations of the Department of Agriculture, have also been reported in U. S. Dept. Agr., Office of Experiment Stations Buls. 21, 44, 63, and 69.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 53.

tion, divided into three periods. During two periods the subject had little or no muscular work, and during the third he had more or less active muscular exercise. The digestibility of the diet and the balance of income and outgo of nitrogen were determined in all the periods. During the majority of the work periods and some of the rest periods the outgo of nitrogen in the urine was determined in portions corresponding to six-hour intervals.

In conducting these experiments several young men in good health and with apparently normal digestion were chosen as subjects. They were accustomed to perform little muscular work. They selected a diet for the experiment which was not so monotonous as to become distasteful, although it was not as varied as is found in the ordinary household. The amounts and proportions of the different food materials conformed to individual taste and remained the same throughout the experiments, except that certain changes were introduced to secure nitrogen equilibrium. Furthermore, energy-yielding food was added during the period when the subject was at muscular work. The central idea of the investigation was to conduct an experiment with a subject in approximate nitrogen equilibrium in which a period of work was preceded by a period of rest, the diet remaining the same, except that during the work period material was added presumably sufficient in amount to increase the fuel value more than enough to compensate for the energy expended in the muscular work performed. In order to bring the subject into a condition of nitrogen equilibrium as rapidly as possible it was thought best, after the diet was decided upon, to determine the balance of income and outgo of nitrogen for a short period, which has been designated the first rest period, and then to increase or decrease the amount of nitrogen in the diet according as the subject showed a gain or loss. A second rest period of two or three days' duration usually served to bring about approximate nitrogen equilibrium. This period was then followed by a third, in which muscular work was performed and the fuel value of the daily diet was increased 500 to 1,000 calories, and at the same time the nitrogen in the daily diet was increased little or none.

It has been held that muscular work is performed mainly at the expense of nitrogenous material, but most physiologists believe that the nonnitrogenous nutrients furnish the chief part of the energy used for muscular work. In the experiments here reported it was believed that the conditions were such that if the former theory were correct there would be an increase in the nitrogen excreted during the work period.

It was also believed that the experimental conditions were such that the effect of muscular work upon digestibility could be studied;

that is, it could be ascertained whether a man digests the same amount from a given diet when at rest as when at work, or whether the digestibility is increased or diminished.

### THE DAILY DIET.

As already stated, the amounts of food eaten were selected by the subjects during the rest period in accordance with their desire. The kinds of food were limited somewhat in order to secure more easily a uniform diet. The diet was arbitrarily increased, especially as regards energy-furnishing food, during the work period. The amounts of food consumed are recorded in all cases, but, owing to the nature of the experiment, they can hardly be considered dietary studies as the term is ordinarily employed. The usual methods of weighing, sampling, and analyzing were generally followed.

### THE DIGESTIBILITY OF FOOD MATERIALS.

Since the value of food for nutriment depends not only upon the kinds and amounts of the several nutrients it contains, but also upon the proportions of these nutrients which can be utilized in the body, it is desirable to obtain as much exact data as possible concerning these proportions. It has been customary to consider the dry matter of the feces as a measure of the amount of undigested nutrients in the food eaten, although it is well understood that this involves an error, since the feces include, in addition to the actually undigested residues of the food, a considerable amount of metabolic products; i. e., products derived from food previously consumed, but which are necessary in order to fit the food for absorption from the alimentary canal.[1] These metabolic products consist of mucus, gastric, pancreatic, and other digestive secretions with residues of the bile and, in addition, more or less epithelial débris from the intestinal walls. Since the metabolic products are necessary for the digestion and absorption of food materials, it is not inaccurate to consider such metabolic products in the feces taken in connection with the true undigested residues as a measure of the nutrients of the food which are not available for use in the body for purposes of building or repair of tissue or yielding energy.

It is the usual custom to compare food materials according to the proportion of total nutrients which they contain. This does not, however, of necessity give a true measure of their relative value as food, since the nutrients of one material may be more largely digestible than those of another. It is desirable to obtain coefficients for the digestibility of the different nutrients in different kinds of food materials and in mixed diet.

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[1] See U. S. Dept. Agr., Office of Experiment Stations Bul. 53.

It has been found that the digestibility of the nutrients as determined by digestion experiments with single food materials differs from the digestibility of the nutrients in the same material when eaten with other foods in a mixed diet. The digestion experiments here reported serve to throw light upon the digestibility of the different kinds of nutrients as found in mixed diet, and in this way are of value in addition to the help they afford in the study of the relation of muscular activity to digestibility and nitrogen metabolism.

The method by which digestion experiments are carried on has been described in detail in a previous bulletin of this series.[1] In brief, it consists in weighing and analyzing the food materials consumed by the subject during a given period of time, usually from two to six days, and collecting and analyzing the feces from the food for a corresponding period. The feces were separated by the usual method of giving lampblack in capsules.

## INCOME AND OUTGO OF NITROGEN.

In these experiments the income and outgo of nitrogen were determined in the usual way. The amount and composition of the various food materials consumed during a given period serve for the computation of the income of nitrogen. The outgo is similarly found from the amount and composition of the feces and of the urine. The comparison of income and outgo shows whether the subject is in nitrogen equilibrium or is gaining or losing nitrogenous matter. As practically all the nitrogen leaves the body in the urine, the latter gives a measure of the actual metabolism of nitrogenous material within the body. There is of necessity a certain interval between the ingestion of an increased amount of protein in the food or the breaking down of an increased amount of nitrogenous material in the body and the elimination of the nitrogen in the urine. Concerning the exact duration of this interval, or the nitrogen lag, as it is frequently called, and the conditions affecting it, comparatively few exact data are as yet available. In order to obtain data concerning this lag, in many of the experiments reported beyond the urine was collected in portions corresponding to six-hour intervals and its nitrogen determined.[2]

## KIND OF MUSCULAR EXERCISE AND MEASUREMENT OF WORK.

In that period of each experiment in which the subject performed external muscular work it was desirable to obtain a more or less accurate idea of the amount of work performed. It was also desirable to

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 53, p. 27.

[2] For a more detailed discussion of the subject of nitrogen lag in the urine see U. S. Dept. Agr., Office of Experiment Stations Buls. 44, p. 35; 53, p. 45; and Connecticut Storrs Station Rpt. 1896, p. 102.

have the work quite severe. Three methods were employed for performing the work and measuring its amount.

(1) *The friction machine.*—This device consisted of a stand carrying a horizontal spindle about 4 feet from the floor. At one end of the spindle was a crank; at the other end, a grooved pulley. Over this pulley passed a cord weighted at one end and fastened by a spring balance to the floor at the other end. A self-regulating apparatus measured the number of revolutions of the crank handle. The diameter of the wheel, length of crank handle, number of revolutions of the crank, and the average tension of the spring furnished the data used for computing the amount of work done each day. In some of the experiments the subject worked as long upon this machine as was practicable without excessive bodily fatigue. Of course, the character of the machine did not permit a high degree of efficiency; that is, the ratio of the heat equivalent of the work performed with the machine to the extra energy supplied in the food was small. It is probable, therefore, that the actual muscular activity of the subject was much greater than would be indicated by the measured work as determined by this machine.

(2) *The stationary bicycle.*—A clamp easily regulated to give much or little friction was fastened so as to grasp the rear wheel of a stationary bicycle. The machine was calibrated for different amounts of friction. This method was not used in the experiments of 1898.

(3) *Walking up and down hill.*—During the experiments of 1899 the external muscular work consisted, in part, of walking up and down hill. A smooth walk on a hill of 140 feet elevation was used. The amount of external muscular work performed which can be measured is the product of the weight of the subject, the number of feet which his body is vertically raised each trip, and the number of trips—i. e., weight × number of trips uphill × 140 = foot-pounds of work. The energy used for the motion of forward progression has never been satisfactorily measured so far as can be learned. The amount of work done by a man walking downhill is an unknown quantity. It may be assumed that he performs the work necessary for forward progression and resists the tendency of gravity to draw him rapidly to the foot of the hill, which requires the expenditure of a certain amount of energy within the body. Although a part of the work in walking downhill is what is termed negative work, it should be taken into account in any discussion of the total amount of muscular work done. A study of the literature of the subject indicates that no satisfactory method of measuring or calculating these factors is available. Therefore, in the discussion of the experiments in which muscular work was performed by walking up and down hill, only that quantity is stated which could be measured—namely, the product of the weight of the body and the total height it was raised. This seems

sufficient for the purpose of these experiments, since the object was to require of the subject an amount of muscular work sufficient to induce fatigue, and to compare the amount of work of different subjects and of the same subject in different periods. The factors which were not measured in these experiments have not been generally taken into account in similar experiments previously reported with which the author is familiar.

A machine is now being constructed upon which it is hoped the subject can work efficiently while at the same time the actual expenditure of force can be more accurately measured.

## PREPARATION, SAMPLING, AND ANALYSIS OF FOOD MATERIALS.

Much care was taken to obtain as representative samples of the different food materials as possible, and only such kinds as permitted of accurate sampling and were of practically uniform composition were used in the diet. The same kinds of food were used to make up the diet during the two years' experiments, and included beef, potted ham, codfish balls, boiled eggs, gelatin jelly, butter, milk, cereal breakfast foods, bread, and potatoes. The meat was generally served in the form of beef loaf, made from finely chopped, lean, cooked beef (either fresh or canned corned beef), with a small amount of flour, etc., added, the whole being compressed into a loaf. Representative slices from different parts of each loaf served for samples. The potted ham was already in condition to permit of accurate sampling, and a sample was taken from each of the cans opened. Codfish balls were prepared by mixing finely divided salt codfish with potatoes and cooking in the usual way. Several of these were taken for analysis from each lot prepared. Eggs were served boiled, and several from each lot taken for analysis. The gelatin was a patent preparation and was used to make a jelly for dessert. The butter used was ordinary farmer's butter, and a sample for analysis was taken from each portion as purchased. Milk was purchased fresh each day, and an aliquot portion taken for the preparation of the composite sample for the different periods. The milk was partially dried and then analyzed in the usual way. The cereal breakfast foods were of several sorts. The corn preparation was one of the rather finely ground breakfast foods called hominy, cracked corn, or grits, and the oatmeal was the ordinary partially cooked rolled oats. In the case of both corn and oatmeal the sample for analysis was taken before cooking. The amount of dry hominy or oatmeal consumed was determined from the total weight of dry cereal used. The bread used was generally the so-called Vienna loaf. One or more representative slices were taken from each loaf for analysis. Potatoes were served in the form of potato chips—i. e., potatoes sliced thin and

fried in deep fat. As representative samples as possible were taken of the cooked material. It will be noticed that, as might be expected, these contained a large proportion of fat and consequently had a high heat of combustion.

## COMPOSITION OF FOOD MATERIALS AND FECES.

In order to determine the balance of income and outgo of nitrogen and the digestibility of the food, it is necessary to know the composition of the food and feces. The foods and excretory products were analyzed by the method adopted by the Association of Official Agricultural Chemists,[1] with such modifications as have been suggested by Atwater and Woods[2] and with minor variations such as have been found advisable in this laboratory.

Table 1 shows the composition of the food materials used in the investigations conducted in 1898 and 1899, which are reported in the following pages. Table 2 shows the composition of the water-free feces of these experiments. The proportion of nitrogen in the different food materials is shown in Table 1. These values are used in computing the income and outgo of nitrogen in the different experiments. In the digestion experiments protein has been calculated as $N \times 6.25$. While this involves more or less error, especially in connection with the proteids of the cereals, which contain more than 16 per cent of nitrogen, no attempt is made to employ any other factor. Should such computations be desired at any time, they can readily be made from the statistics published in this report.

The values in the last column of the table, "Energy per gram," show the heat of combustion of the different materials as determined by means of the bomb calorimeter.[3]

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[1] U. S. Dept. Agr., Division of Chemistry Bul. 48.

[2] Connecticut Storrs Station Rpt. 1891, p. 47.

[3] These combustions were made at Middletown, Conn., by courtesy of Professor Atwater. A bomb calorimeter has since been added to the equipment of this laboratory, and the heat of combustion of the food materials used in the investigations now in progress is determined in connection with the other analytical data.

TABLE 1.—*Composition of food materials.*

| Laboratory number. | Food materials. | Water. | Nitrogen. | Protein (N×6.25). | Fat. | Carbohydrates. | Ash. | Energy per gram. |
|---|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Calories.* |
| 273 | Beef, Hamburg steak | 63.57 | 3.80 | 23.75 | 7.66 | 1.96 | 3.06 | 2.111 |
| 287 | do | 59.08 | 3.71 | 23.19 | 10.83 | 4.04 | 2.86 | 2.446 |
| 296 | do | 45.13 | 4.83 | 30.19 | 13.39 | 5.82 | 5.47 | 3.186 |
| 448 | do | 56.80 | 4.10 | 25.63 | 13.95 | ..... | 3.79 | 2.586 |
| 332 | Beef, canned, corned | 54.95 | 3.80 | 23.75 | 17.11 | ..... | 4.17 | 2.937 |
| 405 | do | 53.99 | 3.64 | 22.75 | 20.14 | ..... | 3.68 | 3.040 |
| 429 | do | 59.17 | 4.03 | 25.19 | 10.84 | ..... | 4.52 | 2.311 |
| 334 | Gelatin preparation | 1.08 | .89 | 5.56 | .61 | 92.50 | .25 | 3.930 |
| 431 | do | 1.16 | .99 | 6.19 | .46 | 92.03 | .16 | 3.960 |
| 451 | do | .85 | 1.01 | 6.31 | 1.05 | 91.62 | .17 | 3.971 |
| 331 | Pork, potted ham | 47.22 | 3.07 | 19.19 | 29.46 | ..... | 4.13 | 3.718 |
| 272 | Fish, codfish balls | 49.39 | 3.05 | 19.06 | 9.76 | 18.65 | 3.14 | 2.734 |
| 286 | do | 57.90 | 2.74 | 17.13 | 7.77 | 13.82 | 3.38 | 2.258 |
| 295 | do | 45.21 | 3.10 | 19.37 | 10.36 | 21.97 | 3.09 | 2.995 |
| 306 | do | 54.20 | 3.03 | 18.94 | 9.12 | 13.71 | 4.03 | 2.501 |
| 323 | do | 50.87 | 3.72 | 23.25 | 8.92 | 11.64 | 5.32 | 2.601 |
| 333 | Eggs | 74.25 | 2.24 | 14.00 | 10.77 | ..... | .97 | 1.813 |
| 449 | do | 73.67 | 2.08 | 13.00 | 11.17 | ..... | .99 | 1.787 |
| 277 | Butter | 13.24 | .20 | 1.25 | 82.11 | ..... | 3.42 | 8.137 |
| 289 | do | 12.52 | .17 | 1.06 | 83.61 | ..... | 2.81 | 7.372 |
| 299 | do | 12.94 | .21 | 1.31 | 82.91 | ..... | 2.84 | 6.171 |
| 310 | do | 13.50 | .20 | 1.25 | 83.01 | ..... | 2.24 | 7.836 |
| 335 | do | 16.06 | .20 | 1.25 | 74.04 | ..... | 8.65 | 7.073 |
| 406 | do | 8.18 | .13 | .81 | 87.95 | ..... | 3.06 | 9.235 |
| 430 | do | 8.25 | .23 | 1.44 | 87.18 | ..... | 3.13 | 8.842 |
| 450 | do | 12.58 | .20 | 1.25 | 83.31 | ..... | 2.86 | 7.843 |
| 274 | Milk | 83.66 | .70 | 4.38 | 6.33 | 4.85 | .78 | 1.048 |
| 288 | do | 83.61 | .75 | 4.69 | 6.35 | 4.58 | .77 | 1.039 |
| 298 | do | 83.69 | .70 | 4.38 | 6.09 | 5.08 | .76 | 1.012 |
| 304 | do | 83.32 | .72 | 4.50 | 6.47 | 4.90 | .81 | 1.046 |
| 316 | do | 83.54 | .70 | 4.38 | 6.59 | 4.73 | .76 | 1.052 |
| 322 | do | 83.61 | .70 | 4.38 | 6.47 | 4.77 | .77 | 1.031 |
| 328 | do | 83.37 | .72 | 4.50 | 6.59 | 4.76 | .78 | 1.065 |
| 339 | do | 83.28 | .71 | 4.44 | 6.46 | 5.05 | .77 | 1.090 |
| 343 | do | 83.51 | .68 | 4.25 | 6.35 | 5.11 | .77 | 1.063 |
| 401 | do | 84.08 | .71 | 4.44 | 5.78 | 4.90 | .80 | .980 |
| 414 | do | 83.69 | .71 | 4.44 | 6.15 | 4.91 | .81 | .959 |
| 419 | do | 83.61 | .71 | 4.44 | 6.32 | 4.82 | .81 | 1.013 |
| 425 | do | 83.28 | .72 | 4.50 | 6.65 | 4.76 | .81 | 1.023 |
| 436 | do | 83.40 | .75 | 4.69 | 6.48 | 4.64 | .79 | 1.045 |
| 440 | do | 83.14 | .74 | 4.63 | 6.75 | 4.68 | .80 | 1.014 |
| 444 | do | 87.87 | .51 | 3.19 | 3.47 | 4.71 | .76 | .653 |
| 456 | do | 88.04 | .51 | 3.19 | 3.37 | 4.64 | .76 | .635 |
| 461 | do | 87.51 | .50 | 3.13 | 3.82 | 4.80 | .74 | .680 |
| 308 | Cracked corn or "grits" | 11.54 | 1.49 | 9.31 | 1.27 | 77.47 | .41 | 3.802 |
| 275 | Oatmeal | 7.74 | 2.77 | 17.31 | 6.77 | 66.29 | 1.89 | 4.260 |
| 307 | do | 8.50 | 2.58 | 16.13 | 7.22 | 66.23 | 1.92 | 4.299 |
| 329 | do | 6.85 | 2.46 | 15.38 | 7.34 | 68.41 | 2.02 | 4.295 |
| 402 | do | 7.46 | 2.32 | 14.50 | 7.71 | 68.42 | 1.91 | 4.377 |
| 426 | do | 8.32 | 2.30 | 14.38 | 7.55 | 67.81 | 1.94 | 4.338 |
| 445 | do | 7.62 | 2.57 | 16.06 | 7.87 | 66.48 | 1.97 | 4.417 |
| 271 | Wheat bread | 30.08 | 1.52 | 9.50 | 1.43 | 57.99 | 1.00 | 3.062 |
| 285 | do | 31.83 | 1.48 | 9.25 | 1.52 | 56.43 | .97 | 3.004 |
| 294 | do | 32.62 | 1.47 | 9.17 | 1.08 | 56.22 | .91 | 2.963 |
| 305 | do | 31.48 | 1.52 | 9.50 | 1.05 | 57.00 | .97 | 3.013 |
| 330 | do | 29.85 | 1.44 | 9.00 | 1.14 | 59.03 | .98 | 3.032 |
| 404 | do | 32.11 | 1.40 | 8.75 | 1.10 | 57.17 | .87 | 2.786 |
| 428 | do | 36.20 | 1.33 | 8.31 | 1.09 | 53.54 | .86 | 2.587 |
| 447 | do | 33.17 | 1.45 | 9.06 | 1.11 | 55.69 | .97 | 2.838 |
| 276 | Potato chips | 4.18 | 1.12 | 7.00 | 33.89 | 51.33 | 3.60 | 5.592 |
| 297 | do | 4.57 | .99 | 6.19 | 39.18 | 46.58 | 3.48 | 5.894 |
| 309 | do | 2.61 | 1.15 | 7.19 | 32.31 | 54.17 | 3.72 | 5.518 |
| 403 | do | 4.08 | 1.18 | 7.37 | 34.39 | 50.43 | 3.73 | 5.605 |
| 427 | do | 5.49 | 1.13 | 7.06 | 28.28 | 55.62 | 3.55 | 5.309 |
| 446 | do | 4.52 | 1.12 | 7.00 | 34.26 | 50.80 | 3.42 | 5.601 |

TABLE 2.—*Composition of water-free substance of feces.*

| Laboratory number. | | Nitrogen. | Protein (N×6.25). | Fat. | Carbohydrates. | Ash. | Energy per gram. |
|---|---|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* | *Calories.* |
| 278 | Feces | 3.67 | 22.94 | 18.37 | 34.89 | 23.80 | 5.812 |
| 279 | .....do | 4.56 | 28.50 | 25.30 | 20.96 | 25.24 | 5.303 |
| 280 | .....do | 3.87 | 24.19 | 23.06 | 30.23 | 22.52 | 6.128 |
| 290 | .....do | 3.35 | 20.94 | 18.18 | 39.01 | 21.87 | 5.999 |
| 291 | .....do | 4.59 | 28.69 | 18.46 | 26.47 | 26.38 | 4.968 |
| 292 | .....do | 4.56 | 28.50 | 17.33 | 34.97 | 19.20 | 6.009 |
| 300 | .....do | 3.42 | 21.36 | 38.45 | 21.14 | 19.05 | 6.452 |
| 301 | .....do | 4.53 | 28.31 | 32.52 | 15.35 | 23.82 | 5.448 |
| 302 | .....do | 4.55 | 28.44 | 27.27 | 26.30 | 17.99 | 6.252 |
| 311 | .... do | 4.41 | 27.57 | 13.30 | 33.57 | 25.56 | 4.144 |
| 312 | .....do | 4.64 | 29.00 | 15.48 | 27.85 | 27.67 | 5.463 |
| 317 | .....do | 3.95 | 24.69 | 13.66 | 34.98 | 26.67 | 4.842 |
| 318 | .....do | 4.54 | 28.38 | 21.11 | 24.05 | 26.46 | 5.171 |
| 319 | .....do | 3.06 | 19.13 | 16.28 | 40.73 | 23.86 | 5.692 |
| 324 | .....do | 4.31 | 26.94 | 14.41 | 36.00 | 22.65 | 5.202 |
| 325 | .....do | 4.69 | 29.31 | 27.30 | 18.90 | 24.49 | 5.346 |
| 326 | .....do | 3.43 | 21.44 | 15.32 | 40.97 | 22.27 | 6.050 |
| 336 | .....do | 3.67 | 22.94 | 17.69 | 31.33 | 28.04 | 5.112 |
| 337 | .....do | 4.08 | 25.50 | 27.40 | 16.92 | 30.18 | 5.148 |
| 340 | .....do | 3.37 | 21.06 | 19.47 | 33.16 | 26.31 | 5.442 |
| 341 | .....do | 3.98 | 24.88 | 21.44 | 27.12 | 26.56 | 5.525 |
| 344 | .....do | 3.36 | 21.00 | 18.03 | 33.83 | 27.14 | 5.550 |
| 345 | .....do | 3.94 | 24.63 | 25.88 | 22.07 | 27.42 | 5.320 |
| 410 | .....do | 4.29 | 26.81 | 18.29 | 25.67 | 29.23 | 4.839 |
| 411 | .....do | 4.03 | 25.19 | 37.69 | 15.64 | 21.48 | 5.783 |
| 412 | .....do | 3.70 | 23.13 | 16.90 | 38.05 | 21.92 | 5.823 |
| 415 | .....do | 4.32 | 27.00 | 14.94 | 30.42 | 27.64 | 4.838 |
| 416 | .....do | 4.91 | 30.69 | 30.54 | 17.49 | 21.28 | 5.404 |
| 417 | .....do | 4.20 | 26.25 | 18.24 | 34.59 | 20.92 | 5.618 |
| 420 | .....do | 4.34 | 27.13 | 24.36 | 21.91 | 26.60 | 5.030 |
| 421 | .....do | 4.96 | 31.00 | 33.70 | 14.77 | 20.53 | 5.420 |
| 422 | .....do | 4.42 | 27.63 | 25.37 | 28.09 | 18.91 | 5.815 |
| 433 | .....do | 4.28 | 26.75 | 24.80 | 22.18 | 26.27 | 5.023 |
| 434 | .....do | 3.42 | 21.38 | 26.15 | 22.97 | 29.50 | 5.512 |
| 437 | .....do | 4.24 | 26.50 | 17.41 | 29.94 | 26.15 | 4.822 |
| 438 | .....do | 4.36 | 27.25 | 24.74 | 27.59 | 20.42 | 5.197 |
| 441 | .....do | 4.29 | 26.81 | 21.30 | 26.89 | 25.00 | 4.898 |
| 442 | .....do | 5.08 | 31.75 | 29.76 | 18.27 | 20.22 | 5.213 |
| 452 | .....do | 4.99 | 31.19 | 22.19 | 19.64 | 26.98 | 4.565 |
| 453 | .....do | 4.95 | 30.93 | 17.04 | 23.10 | 28.93 | 4.258 |
| 454 | .....do | 4.62 | 28.88 | 19.97 | 27.35 | 23.80 | 4.819 |
| 457 | .....do | 4.34 | 27.12 | 20.81 | 22.80 | 29.27 | 4.595 |
| 458 | .....do | 4.75 | 29.69 | 18.01 | 21.46 | 30.84 | 4.232 |
| 459 | .....do | 4.91 | 30.69 | 12.55 | 31.26 | 25.50 | 4.761 |
| 462 | .....do | 4.31 | 26.94 | 22.84 | 22.57 | 27.65 | 4.899 |
| 463 | .....do | 4.66 | 29.13 | 19.32 | 24.46 | 27.09 | 4.694 |
| 464 | .....do | 5.37 | 33.56 | 23.38 | 22.98 | 20.08 | 5.134 |
| 475 | .....do | 5.92 | 37.00 | 11.21 | 29.55 | 22.24 | ..... |
| 476 | .....do | 5.92 | 37.00 | 8.36 | 30.22 | 24.42 | ..... |
| 477 | .....do | 6.04 | 37.75 | 6.47 | 31.08 | 24.70 | ..... |

## EXPERIMENTS CARRIED ON IN 1897–98.

In the present report the results of experimental investigation during two years are given. The plan of investigation differed slightly during the second year from that followed in the first, and the work of each year is treated separately.

During the late fall of 1897 and winter of 1898 eight complete experiments were carried on with three different subjects. In order to save unnecessary analytical labor two or three experiments were carried on contemporaneously. Each subject selected his own diet as regards proportions and actual quantities of the different materials, but the kinds were the same in each group of experiments.

The supper preceding each experiment consisted largely of bread and milk. Each experimental period commenced with breakfast, at

which time about one-half gram of lampblack was taken to color the feces and permit of a separation of portions pertaining to the different periods of the experiment. It has been found more satisfactory in these experiments to administer the lampblack with the breakfast following a supper consisting largely of bread and milk, rather than with the supper, as has sometimes been done. The charcoal colors the feces of the food following the bread and milk, and since the milk gives a characteristic consistency to the feces a very satisfactory separation can be made, as a rule, of the feces belonging to any period and those belonging to the food of the preceding period.

During the two days of the first rest period analyses of food materials and determination of the nitrogen in the urine were made as rapidly as possible and the nitrogen balance obtained approximately, the assumption being made that the nitrogen in the feces would amount to not far from 1.5 grams per day. On the last day of the interval following this rest period a considerable proportion of the daily allowance of milk was taken for supper, and charcoal was taken the following morning with breakfast in order to mark the feces from the food in the first digestion experiment from those from the food of the second digestion experiment. The diet was so changed during the second digestion experiment, i. e., the second rest period, that, provided other conditions remained the same, the subject would be approximately in nitrogen equilibrium. This second rest period, usually continuing three days, was utilized for a final adjustment of the diet, and, as a rule, the subject was as nearly in nitrogen equilibrium during this period as could be expected. Following the second rest period came an interval during which arrangements were made for an increase in the amount of energy in the diet for the following work period. On the last day of this interval a large proportion of the daily allowance of milk was consumed for supper and the charcoal was taken the following morning, as usual, in order to mark the feces of the two periods for separation. The fats and carbohydrates in the diet during the third or work period were largely increased by the addition of more butter and sugar, but it was also thought desirable to increase the bread somewhat, to make the diet more palatable. During some of the earlier experiments there was no reduction in the other foods containing nitrogen to offset that added in the bread, and consequently there was a slight increase in the amount furnished by the food during the work period as compared with the preceding rest period.

The external muscular work in the experiments of 1898 was performed with the friction machine already described. The nature of the machine did not admit of attaining great efficiency and the work performed by the subject was undoubtedly much greater than is indicated by the actual measurements. In fact, the two or three hours per day devoted to this machine furnished all the work which the subjects cared to do. Judging solely from the heat equivalent of the

work measured, it would appear that the muscular activity was very slight. The subjects, however, experienced considerable bodily fatigue in the performance of the work.

It was found in the first few experiments that the addition of food furnishing 1,000 calories of energy was too great, for the diet became distasteful. In some of the later experiments material was added sufficient to furnish only 500 or 600 calories increase, and the diet was very satisfactory.

The experiments were made with three men. A was the subject in Nos. 1, 4, and 7; B Nos. 2, 5, and 8, and C in Nos. 3 and 6. Experiments Nos. 1, 2, and 3 were carried along contemporaneously, followed by Nos. 4, 5, and 6, and finally by Nos. 7 and 8.

The schedule below gives a general plan of the arrangement of these experiments and the duration of the different periods. Thus in metabolism experiment No. 1, after a preliminary period of short duration, digestion experiment No. 53 was begun and continued four days, the first two of which form the first rest period. The urine was collected for these two days and the digestion experiment has been calculated for these two days on the assumption that the amount of feces was half that excreted during the four days of the digestion experiment proper. Following the interval of two days during which the nitrogen balance was calculated, came the second rest period (digestion experiment No. 54) with changed diet, which actually continued four days. The last day, however, has not been included, although the kinds and amounts of food consumed were the same. The urine having been collected for but three days, the digestion experiment has been calculated for these three days upon the assumption that the amount of feces was three-quarters that eliminated in the four days. Following this came the work period (digestion experiment No. 55) continuing two days, in which the diet was largely increased in energy and the subject worked with the friction machine from two to four hours each day.

TABLE 3.—*General scheme of experiments Nos. 1–8.*

| Number of experiment. | Subject. | Preliminary period, diet selected. | First rest period, diet tested. | | Interval with same diet as in first rest period. | Second rest period, diet adjusted. | | Interval with same diet as in second rest period. | Work period, diet increased. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number of digestion experiment. | Duration. | | Number of digestion experiment. | Duration. | | Number of digestion experiment. | Duration. |
| | | | | *Days.* | *Days.* | | *Days.* | *Days.* | | *Days.* |
| 1 | A | Duration variable. | 53 | 2 | 2 | 54 | 3 | 1 | 55 | 2 |
| 2 | B | | 56 | 2 | 2 | 57 | 3 | 1 | 58 | 2 |
| 3 | C | | 59 | 2 | 2 | 60 | 3 | 1 | 61 | 2 |
| 4 | A | | 62 | 2 | 1 | 63 | 3 | 1 | 64 | 4 |
| 5 | B | | 65 | 2 | 1 | 66 | 3 | 1 | 67 | 4 |
| 6 | C | | ..... | ..... | ..... | 68 | 3 | 1 | 69 | 4 |
| 7 | A | | 70 | 2 | 1 | 71 | 2 | 2 | 72 | 3 |
| 8 | B | | 73 | 2 | 1 | 74 | 2 | 2 | 75 | 3 |

The statistical details of these experiments are shown in the tables which follow.

### EXPERIMENT NO. 1.

This experiment was carried on with a chemist 22 years of age, in good health, and weighing at the beginning 62.37 kilograms and at the end 62.69 kilograms. After a short preliminary period, during which the diet was selected, the experiment began with breakfast January 10. The first rest period (digestion experiment No. 53) continued two days and included six meals. The kind of food material eaten and amounts of nutrients and of energy available are shown in Table 4. The quantities of protein, fats and carbohydrates, ash and nitrogen, and the total heat of combustion in this and the following experiments are computed from the total weights of the different food materials consumed and their percentage composition as shown in Table 1, page 14. In a similar manner the outgo of nutrients and energy in the feces are computed from the total weight of dried feces and their percentage composition as shown in Table 2. The differences between the nutrients in the food eaten and those rejected in the feces give the amount available for use in the body, from which are calculated the coefficients of digestibility. The amount and composition of the urine during each period are stated after the tabular details of each digestion experiment. The heat of combustion was not determined, but was assumed from the average of a considerable number of determinations made by Atwater and associates as explained in a previous publication of this series.[1] The sum of the energy lost to the body in the feces and urine deducted from the total energy in the food shows the energy of food oxidized in the body and gives data for computing the percentage of energy utilized.

While the first digestion experiment was being carried on the food materials were analyzed as rapidly as possible, and at the close of the period there was an interval of two days during which the subject continued upon the same diet as during the period proper. The necessary analyses were completed to determine whether or not the subject was in approximate nitrogen equilibrium. It was found that he gained 8¼ grams of nitrogen during the two days, and consequently the diet was changed by reducing considerably the amount of milk, so as to furnish less nitrogen. The second rest period (digestion experiment No. 54) began with breakfast January 15. This period continued three days, including nine meals. The subject apparently lost 0.14 kilogram in weight, but still stored a small amount of nitrogen, about 1⅓ grams, per day. At the close of this period there was an interval of one day during which the subject subsisted upon the same diet as in the period proper. The third or work period (digestion experiment No. 55) began with breakfast January 19, 1898. The diet was increased by

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 53, p. 28. The factor used was 1.25, however, instead of 1.35, as further data seem to indicate that the latter factor is slightly too large.

the addition of butter and bread sufficient to add nearly 1,000 calories of energy and 3 grams of nitrogen per day. The large increase in the amount of butter, however, became distasteful before the close of the period. This doubtless accounts for the larger amount of fat eliminated in the feces. During the work period the subject turned the crank of the friction machine already described (p. 11). On January 19 he worked two hours, and, as measured by the machine, performed 126,914 foot-pounds of work. On the following days he worked three hours and performed 221,013 foot-pounds of work, making a total of 347,927 foot-pounds, or 47,990 kilogrammeters[1] for the two days. The mechanical equivalent of 1 calorie is in round numbers 3,100 foot-pounds. The heat equivalent of the work done for these two days was, therefore, 112 calories, or 56 calories per day.

*Details of experiment No. 1.*

*Subject.*—Chemist, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 62.37 kilograms (137.5 pounds); at end of first period, 62.01 kilograms; at beginning of second period, 62.37 kilograms; at end of second period, 62.23 kilograms; at beginning of third period, 62.69 kilograms; at end of third period and experiment, 62.69 kilograms (138.2 pounds).

The experiment commenced with breakfast January 11, 1898, and the first period continued two days. The second period commenced with breakfast January 15 and continued three days. The third period commenced with breakfast January 19 and continued two days.

TABLE 4.—*Results of experiment No. 1.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 53.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 273 | Hamburg steak | 150 | 50 | 5.70 | 36 | 11 | 3 | 5 | 317 |
| 272 | Codfish balls | 106 | 50 | 3.23 | 20 | 10 | 20 | 2 | 290 |
| 277 | Butter | 140 | 117 | .28 | 2 | 115 | ..... | 5 | 1,139 |
| 274 | Milk | 3,200 | 498 | 22.40 | 140 | 203 | 155 | 25 | 3,354 |
| 275 | Oatmeal | 115 | 104 | 3.19 | 20 | 8 | 76 | 3 | 490 |
| 271 | Bread | 464 | 320 | 7.05 | 44 | 7 | 269 | 5 | 1,421 |
| 276 | Potato chips | 70 | 65 | .78 | 5 | 36 | 24 | 3 | 392 |
| ..... | Sugar | 50 | 50 | ..... | ..... | ..... | 50 | ..... | 198 |
| | Total | ..... | 1,254 | 42.63 | 267 | 390 | 597 | 48 | 7,601 |
| 278 | Feces | 66 | 50 | 2.42 | 15 | 12 | 23 | 16 | 384 |
| 281 | Urine | 2,282 | ..... | 31.96 | ..... | ..... | ..... | ..... | *a* 315 |
| | Amount digested | ..... | 1,204 | 40.21 | 252 | 378 | 574 | 32 | 6,902 |
| | Coefficients of digestibility (per cent) | ..... | 96.0 | 94.4 | 94.4 | 96.9 | 96.1 | 66.7 | 90.8 |

*a* Estimated.

[1] Taking 1 kilogrammeter as equal to 7¼ foot-pounds. More accurately it would be equal to 7.233 foot-pounds.

TABLE 4.—*Results of experiment No. 1*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 54.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 287 | Hamburg steak | 225 | 86 | 8.35 | 53 | 24 | 9 | 6 | 550 |
| 286 | Codfish balls | 181 | 70 | 4.96 | 31 | 14 | 25 | 6 | 409 |
| 289 | Butter | 190 | 161 | .32 | 2 | 159 | ..... | 5 | 1,401 |
| 288 | Milk | 3,180 | 497 | 23.85 | 149 | 202 | 146 | 24 | 3,304 |
| 275 | Oatmeal | 155 | 140 | 4.29 | 27 | 10 | 103 | 3 | 660 |
| 285 | Bread | 686 | 461 | 10.15 | 64 | 10 | 387 | 7 | 2,061 |
| ..... | Sugar | 90 | 90 | ..... | ..... | ..... | 90 | ..... | 356 |
| 276 | Potato chips | 105 | 97 | 1.18 | 7 | 36 | 54 | 4 | 587 |
| | Total | ..... | 1,602 | 53.10 | 333 | 455 | 814 | 55 | 9,328 |
| 290 | Feces | 80 | 63 | 2.68 | 17 | 15 | 31 | 17 | 480 |
| 293 | Urine | 2,715 | ..... | 46.43 | ..... | ..... | ..... | ..... | *a* 395 |
| | Amount digested | ..... | 1,539 | 50.42 | 316 | 440 | 783 | 38 | 8,453 |
| | Coefficients of digestibility (per cent) | ..... | 96.1 | 94.9 | 94.9 | 96.7 | 96.2 | 69.1 | 90.6 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 55.*) | | | | | | | | |
| 296 | Hamburg steak | 150 | 74 | 7.25 | 45 | 20 | 9 | 8 | 478 |
| 295 | Codfish balls | 118 | 61 | 3.66 | 23 | 12 | 26 | 4 | 353 |
| 299 | Butter | 252 | 212 | .53 | 3 | 209 | ..... | 7 | 1,555 |
| 298 | Milk | 2,120 | 330 | 14.84 | 93 | 129 | 108 | 16 | 2,145 |
| 275 | Oatmeal | 100 | 90 | 2.77 | 17 | 7 | 66 | 2 | 426 |
| 294 | Bread | 805 | 535 | 11.83 | 74 | 9 | 452 | 7 | 2,385 |
| ..... | Sugar | 70 | 70 | ..... | ..... | ..... | 70 | ..... | 277 |
| 297 | Potato chips | 70 | 64 | .69 | 4 | 27 | 33 | 2 | 413 |
| | Total | ..... | 1,436 | 41.57 | 259 | 413 | 764 | 46 | 8,032 |
| 300 | Feces | 46 | 37 | 1.57 | 10 | 17 | 10 | 9 | 297 |
| 303 | Urine | 2,004 | ..... | 32.57 | ..... | ..... | ..... | ..... | *a* 311 |
| | Amount digested | ..... | 1,399 | 40.00 | 249 | 396 | 754 | 37 | 7,424 |
| | Coefficients of digestibility (per cent) | ..... | 97.4 | 96.1 | 96.1 | 95.9 | 98.7 | 80.4 | 92.4 |

*a* Estimated.

The urine of the two days of the first rest period was collected during three unequal intervals and amounted to 1,311 grams with 1.33 per cent nitrogen; 184 grams with 1.56 per cent nitrogen, and 787 grams with 1.48 per cent nitrogen, or a total of 2,282 grams of urine with 31.96 grams of nitrogen.

The urine for the three days of the second rest period amounted to 2,715 grams, containing 1.71 per cent nitrogen or 46.43 grams nitrogen.

For the two days of the work period the urine was collected during four intervals, two of six hours and two of eighteen hours each. The results, beginning January 19, are as follows: 8 a. m. to 2 p. m., 125 grams urine, 1.52 per cent nitrogen; 2 p. m. to 8 a. m., 825 grams, 1.55 per cent nitrogen; 8 a. m. to 2 p. m., 273 grams, 1.40 per cent nitro-

gen, and 2 p. m. to 8 a. m., 781 grams, 1.80 per cent nitrogen. The total urine for the two days thus amounted to 2,004 grams, containing 32.57 grams of nitrogen.

From the data given above and the figures for the nitrogen content of the food and feces included in Tables Nos. 1 and 2 the average daily balance of income and outgo of nitrogen in the two periods of rest and the period of work was calculated. The results follow:

TABLE 5.—*Daily income and outgo of nitrogen in experiment No. 1.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 21.32 | 1.21 | 15.98 | 4.13 |
| Second period, rest, adjusted diet | 3 | 17.70 | .89 | 15.48 | 1.33 |
| Third period, work, diet increased 3.1 grams nitrogen and 907 calories | 2 | 20.79 | .79 | 16.29 | 3.71 |

Some of the points brought out by the figures in the table have been spoken of already. The influence of muscular work on the cleavage of protein in the body and on the excretion of nitrogen in the urine can be more satisfactorily discussed by considering the experiments as a whole than by taking up the individual experiments. Such a discussion follows the work of each year (pp. 41 and 70). The result of the two series of experiments are also summarized (p. 75).

## EXPERIMENT NO. 2.

This experiment was carried on at the same time as experiment No. 1. The subject was a chemist, 28 years of age, in normal health and weighing, without clothes, 66.09 kilograms at the beginning of the experiment and 65.52 kilograms at its close. The usual preliminary period preceded the first rest period of the experiment (digestion experiment No. 56). The diet consisted of the same kinds of food materials as in experiment No. 1, but in different proportions. The details of the digestion experiment are shown in Table 6. During the first rest period the subject was not quite in nitrogen equilibrium. The proportions of the different foods consumed, therefore, were slightly changed during the second rest period (digestion experiment No. 57), which involved a slight increase in the amount of nitrogen in the ration amounting to 0.9 gram per day. During the three days there was a gain of nearly 4 grams of nitrogen, or 1⅓ grams per day. A period of two days intervened between the first and second rest periods, during which time the foods were analyzed as in experiment No. 1. After an interval of one day the second rest period was followed by the third or work period of the experiment (digestion experiment No. 58). A larger amount of bread and butter was eaten during this period than before. This increased the energy about 1,000 calo-

ries per day and the nitrogen 2.8 grams. The increase in the amount of butter added was distasteful, as in experiment No. 1, which probably accounts for the fact that there was a larger amount of fat eliminated in the feces than during the previous periods of this experiment. The subject gained during the two days 8.25 grams of nitrogen, or over 4 grams per day. He worked about two hours a day with the friction machine, performing, according to its measurements, 96,322 foot-pounds of work on the first day and 167,886 foot-pounds the second day, making a total of 264,208 foot-pounds or 36,443 kilogrammeters, the heat equivalent of which is 85 calories, or an average of 43 calories per day. During this work experiment although the subject gained nitrogen there was an apparent loss of 0.43 kilogram in body weight.

*Details of experiment No. 2.*

*Subject.*—Chemist, 28 years of age.

*Weight (without clothing).*—At beginning of experiment, 66.09 kilograms (145.7 pounds); at end of first period, 66.10 kilograms; at beginning of second period, 66.09 kilograms; at end of second period, 65.77 kilograms; at beginning of third period, 65.95 kilograms; at end of third period and experiment, 65.52 kilograms (144 pounds).

The experiment commenced with breakfast January 11, 1898, and the first period continued two days. The second period commenced with breakfast January 15 and continued three days. The third period commenced with breakfast January 19 and continued two days.

TABLE 6.—*Results of experiment No. 2.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. TRIAL DIET. REST. (*Digestion experiment No. 56.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 273 | Hamburg steak | 210 | 70 | 7.98 | 50 | 16 | 4 | 6 | 443 |
| 272 | Codfish balls | 111 | 53 | 3.39 | 21 | 11 | 21 | 3 | 303 |
| 277 | Butter | 40 | 33 | .08 | ..... | 33 | ..... | 1 | 325 |
| 274 | Milk | 3,200 | 498 | 22.40 | 141 | 202 | 155 | 25 | 3,354 |
| 275 | Oatmeal | 115 | 104 | 3.19 | 20 | 8 | 76 | 3 | 490 |
| 271 | Bread | 444 | 306 | 6.75 | 42 | 6 | 258 | 4 | 1,360 |
| ..... | Sugar | 70 | 70 | ..... | ..... | ..... | 70 | ..... | 277 |
| 276 | Potato chips | 60 | 55 | .67 | 4 | 20 | 31 | 2 | 336 |
| | Total | ..... | 1,189 | 44.46 | 278 | 296 | 615 | 44 | 6,888 |
| 279 | Feces | 58 | 43 | 2.64 | 16 | 15 | 12 | 15 | 308 |
| 281a | Urine | 2,070 | ..... | 41.59 | ..... | ..... | ..... | ..... | *a* 328 |
| | Amount digested | ..... | 1,146 | 41.82 | 262 | 281 | 603 | 29 | 6,252 |
| | Coefficients of digestibility (per cent) | ..... | 96.4 | 94.2 | 94.2 | 94.9 | 98.0 | 65.9 | 90.8 |

*a* Estimated.

TABLE 6.—*Results of experiment No. 2*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 57.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 287 | Hamburg steak | 315 | 120 | 11.68 | 73 | 34 | 13 | 9 | 770 |
| 286 | Codfish balls | 194 | 75 | 5.32 | 33 | 15 | 27 | 5 | 438 |
| 289 | Butter | 50 | 42 | .09 | ..... | 42 | ..... | 1 | 369 |
| 288 | Milk | 4,800 | 750 | 36.00 | 225 | 305 | 220 | 37 | 4,987 |
| 275 | Oatmeal | 185 | 167 | 5.12 | 32 | 12 | 123 | 3 | 788 |
| 285 | Bread | 706 | 474 | 10.45 | 65 | 11 | 398 | 7 | 2,121 |
| ..... | Sugar | 90 | 90 | ..... | ..... | ..... | 90 | ..... | 356 |
| 276 | Potato chips | 65 | 60 | .73 | 5 | 22 | 33 | 2 | 363 |
| | Total | ..... | 1,778 | 69.39 | 433 | 441 | 904 | 64 | 10,192 |
| 291 | Feces | 84 | 62 | 3.86 | 24 | 16 | 22 | 22 | 417 |
| 293a | Urine | 3,643 | ..... | 61.57 | ..... | ..... | ..... | ..... | *a* 511 |
| | Amount digested | ..... | 1,716 | 65.53 | 409 | 425 | 882 | 42 | 9,264 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 94.5 | 94.5 | 96.4 | 97.6 | 65.6 | 90.9 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 58.*) | | | | | | | | |
| 296 | Hamburg steak | 210 | 104 | 10.14 | 64 | 28 | 12 | 11 | 669 |
| 295 | Codfish balls | 128 | 66 | 3.97 | 25 | 13 | 28 | 4 | 383 |
| 299 | Butter | 182 | 153 | .38 | 2 | 151 | ..... | 5 | 1,123 |
| 298 | Milk | 3,200 | 498 | 22.40 | 140 | 195 | 163 | 24 | 3,238 |
| 275 | Oatmeal | 120 | 108 | 3.32 | 21 | 8 | 79 | 2 | 511 |
| 294 | Bread | 761 | 506 | 11.18 | 70 | 8 | 428 | 7 | 2,255 |
| ..... | Sugar | 60 | 60 | ..... | ..... | ..... | 60 | ..... | 238 |
| 297 | Potato chips | 44 | 40 | .44 | 3 | 17 | 20 | 2 | 259 |
| | Total | ..... | 1,535 | 51.83 | 325 | 420 | 790 | 55 | 8,676 |
| 301 | Feces | 61 | 46 | 2.76 | 17 | 20 | 9 | 15 | 332 |
| 303a | Urine | 2,170 | ..... | 40.82 | ..... | ..... | ..... | ..... | *a* 385 |
| | Amount digested | ..... | 1,489 | 49.07 | 308 | 400 | 781 | 40 | 7,959 |
| | Coefficients of digestibility (per cent) | ..... | 97.0 | 94.8 | 94.8 | 95.2 | 98.9 | 72.7 | 91.7 |

*a* Estimated.

The urine during the two days of the first rest period was collected and analyzed in three unequal portions. The statistical data are as follows: 1,162 grams of urine, with 2 per cent nitrogen; 298 grams of urine, with 1.96 per cent nitrogen; 610 grams urine, with 2.05 per cent nitrogen, or 2,070 grams of urine, containing 41.59 grams nitrogen.

One composite sample of urine was collected for the three days of the second rest period. The total amount was 3,643 grams, with 1.69 per cent, or 61.57 grams nitrogen.

The urine for the two days of the work period was collected during four periods, two of six hours and two of eighteen hours each. Beginning at 8 a. m., January 19, the results were as follows: 8 a. m. to 2 p. m., 213 grams, with 1.87 per cent nitrogen; 2 p. m. to 8 a. m., 821 grams, with 2 per cent nitrogen; 8 a. m. to 2 p. m., 316 grams,

with 1.66 per cent nitrogen, and 2 p. m. to 8 a. m., 820 grams, with 1.85 per cent nitrogen. The total amount of urine eliminated during the two days amounted to 2,170 grams, containing 40.82 grams nitrogen.

The average daily balance of income and outgo of nitrogen in the three periods is shown in the following table:

TABLE 7.—*Daily income and outgo of nitrogen in experiment No. 2.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 22.23 | 1.32 | 20.80 | 0.11 |
| Second period, rest, adjusted diet | 3 | 23.13 | 1.29 | 20.52 | 1.32 |
| Third period, work, diet increased 2.8 grams nitrogen and 941 calories | 2 | 25.02 | 1.38 | 20.41 | 4.13 |

## EXPERIMENT NO. 3.

Experiment No. 3 was carried on with a chemist 29 years of age, in good health, weighing 59.97 kilograms without clothes at the beginning of the study and 60.65 kilograms at the end. The detailed data of the digestion experiment are included in Table 8.

The usual preliminary period during which the amounts of the different food materials were decided upon preceded this experiment. The same kinds of food were used as in the two experiments already described. The first rest period (digestion experiment No. 59) began with breakfast January 11 and continued two days. An interval of two days followed the close of this period during which the food materials and urine were analyzed and it was found that the subject was storing nitrogen at the rate of 6.35 grams per day. The diet was therefore altered by reducing the amount of milk 900 grams per day. It is interesting to note that the subject had been living on a scanty diet before the experiment began, which probably accounted for the large gain in nitrogen as soon as the food was more abundant.

The second rest period (digestion experiment No. 60) began with breakfast January 15 and continued three days, during which time the subject still gained nitrogen at the rate of 1.54 grams per day although there was an apparent loss in body weight of 0.54 kilogram during the three days. After an interval of one day with the same diet the third or work period (digestion experiment No. 61) was begun. This continued two days, during which time the diet was increased by about 800 calories of energy and 3 grams of nitrogen per day. The actual work measured during the two days was 340,453 foot-pounds or 46,959 kilogrammeters. During the first day the subject worked two hours and as shown by the friction machine performed 120,805 foot-pounds of work, and on the second day three hours, with 219,648 foot-pounds of work. The heat equivalent of the work measured was 110 calories for

the two days, or an average of 55 calories per day. There was a gain of nitrogen amounting to 4.09 grams per day, although the subject was apparently losing weight slightly.

*Details of experiment No. 3.*

*Subject.*—Chemist, 29 years of age.

*Weight (without clothing).*—At beginning of experiment, 59.97 kilograms (132.2 pounds); at end of first period, 60.33 kilograms; at beginning of second period, 60.78 kilograms; at end of second period, 60.24 kilograms; at beginning of third period, 61.29 kilograms; at end of third period and experiment, 60.65 kilograms (133.7 pounds).

The experiment commenced with breakfast January 11, 1898, and the first period continued two days. The second period commenced with breakfast January 15 and continued three days. The third period commenced with breakfast January 19 and continued two days.

TABLE 8.—*Results of experiment No. 3.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 59.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 273 | Hamburg steak | 240 | 80 | 9.12 | 57 | 18 | 5 | 7 | 507 |
| 272 | Codfish balls | 197 | 94 | 6.01 | 38 | 19 | 37 | 6 | 539 |
| 277 | Butter | 50 | 42 | .10 | 1 | 41 | ..... | 2 | 407 |
| 274 | Milk | 3,200 | 498 | 22.40 | 141 | 202 | 155 | 25 | 3,354 |
| 275 | Oatmeal | 85 | 77 | 2.35 | 15 | 6 | 56 | 2 | 362 |
| 271 | Bread | 413 | 285 | 6.28 | 39 | 6 | 240 | 4 | 1,265 |
| ..... | Sugar | 115 | 115 | ..... | ..... | ..... | 115 | ..... | 455 |
| 276 | Potato chips | 55 | 51 | .62 | 4 | 19 | 28 | 2 | 308 |
| | Total | ..... | 1,242 | 46.88 | 295 | 311 | 636 | 48 | 7,197 |
| 280 | Feces | 71 | 55 | 2.75 | 17 | 16 | 22 | 16 | 435 |
| 281b | Urine | 1,914 | ..... | 31.42 | ..... | ..... | ..... | ..... | *a* 365 |
| | Amount digested | ..... | 1,187 | 44.13 | 278 | 295 | 614 | 32 | 6,397 |
| | Coefficients of digestibility (per cent) | ..... | 95.6 | 94.2 | 94.2 | 94.9 | 96.5 | 66.7 | 88.9 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 60.*) | | | | | | | | |
| 287 | Hamburg steak | 390 | 148 | 14.47 | 90 | 42 | 16 | 11 | 954 |
| 286 | Codfish balls | 297 | 115 | 8.14 | 51 | 23 | 41 | 10 | 671 |
| 289 | Butter | 60 | 51 | .10 | 1 | 50 | ..... | 2 | 442 |
| 288 | Milk | 2,100 | 328 | 15.75 | 99 | 133 | 96 | 16 | 2,182 |
| 275 | Oatmeal | 165 | 149 | 4.57 | 29 | 11 | 109 | 3 | 703 |
| 285 | Bread | 576 | 387 | 8.52 | 53 | 9 | 325 | 6 | 1,730 |
| ..... | Sugar | 140 | 140 | ..... | ..... | ..... | 140 | ..... | 554 |
| 276 | Potato chips | 75 | 69 | .84 | 5 | 25 | 39 | 3 | 419 |
| | Total | ..... | 1,387 | 52.39 | 328 | 293 | 766 | 51 | 7,655 |
| 292 | Feces | 61 | 49 | 2.78 | 17 | 11 | 21 | 12 | 367 |
| 293b | Urine | 3,147 | ..... | 45.00 | ..... | ..... | ..... | ..... | *a* 389 |
| | Amount digested | ..... | 1,338 | 49.61 | 311 | 282 | 745 | 39 | 6,899 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 94.8 | 94.8 | 96.2 | 97.3 | 76.5 | 90.1 |

*a* Estimated.

TABLE 8.—*Results of experiment No. 3*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | THIRD PERIOD. DIET INCREASED IN NITROGEN AND ENERGY. WORK. (*Digestion experiment No. 61.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 296 | Hamburg steak | 260 | 128 | 12.56 | 15 | 35 | 78 | 14 | 828 |
| 295 | Codfish balls | 198 | 102 | 6.14 | 38 | 20 | 44 | 6 | 593 |
| 299 | Butter | 112 | 94 | .24 | 1 | 93 | ..... | 3 | 691 |
| 298 | Milk | 1,400 | 218 | 9.80 | 62 | 85 | 71 | 11 | 1,417 |
| 275 | Oatmeal | 115 | 104 | 3.19 | 20 | 8 | 76 | 2 | 490 |
| 294 | Bread | 590 | 392 | 8.67 | 54 | 6 | 332 | 5 | 1,748 |
| ..... | Sugar | 160 | 160 | ..... | ..... | ..... | 160 | ..... | 634 |
| 297 | Potato chips | 50 | 46 | .50 | 3 | 20 | 23 | 2 | 295 |
| | Total | ..... | 1,244 | 41.10 | 193 | 267 | 784 | 43 | 6,696 |
| 302 | Feces | 60 | 49 | 2.73 | 17 | 16 | 16 | 11 | 375 |
| 303b | Urine | 2,336 | ..... | 30.19 | ..... | ..... | ..... | ..... | *a* 220 |
| | Amount digested | ..... | 1,195 | 38.37 | 176 | 251 | 768 | 32 | 6,101 |
| | Coefficients of digestibility (per cent) | ..... | 96.1 | 91.2 | 91.2 | 94.0 | 98.0 | 74.4 | 91.1 |

*a* Estimated.

Three samples of urine were collected during the first rest period amounting to 836 grams with 1.72 per cent nitrogen, 227 grams with 1.58 per cent nitrogen, and 851 grams with 1.58 per cent nitrogen. The total urine for the two days thus amounted to 1,914 grams, containing 31.42 grams nitrogen.

The urine during the three days of the second rest period was not collected in periods, but was united to form one portion, which amounted to 3,147 grams, with 1.43 per cent or 45 grams of nitrogen.

The urine during the work period was collected, as in the two previous experiments, in portions corresponding to four periods of unequal length, namely, two of six hours and two of eighteen hours duration. Beginning with the morning of January 19, the statistical details for elimination of urine and nitrogen are as follows: 8 a. m. to 2 p. m., 288 grams urine with 1.30 per cent nitrogen; 2 p. m. to 8 a. m., 907 grams with 1.22 per cent nitrogen, and 2 p. m. to 8 a. m., 902 grams with 1.36 per cent nitrogen. The total elimination of urine for the period was thus 2,336 grams, containing 30.19 grams nitrogen.

In Table 9 is shown the average daily income and outgo of nitrogen and the corresponding gain or loss of this element.

TABLE 9.—*Daily income and outgo of nitrogen in experiment No. 3.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 23.44 | 1.38 | 15.71 | 6.35 |
| Second period, rest, adjusted diet | 3 | 17.46 | .92 | 15.00 | 1.54 |
| Third period, work, diet increased 3.1 grams nitrogen and 797 calories | 2 | 20.55 | 1.36 | 15.20 | 4.09 |

## EXPERIMENT NO. 4.

Experiment No. 4 began a second set with the same subjects as in experiments Nos. 1, 2, and 3. The experiment began with breakfast February 8, 1898, and was preceded as usual by a preliminary period during which the quantities of the different food materials used were selected. The subject was the same as in experiment No. 1 above described. During the first rest period (digestion experiment No. 62) he apparently lost 0.27 kilogram in body weight, although there was a gain of 2.45 grams of nitrogen per day. This period was followed by an interval of two days during which the diet was reduced by 360 grams of milk per day. In the second rest period (digestion experiment No. 63) the subject was more nearly in nitrogen equilibrium, although still gaining 0.63 gram of nitrogen each day. An interval of one day followed the close of this period during which time the food materials were analyzed for the next period and arrangements were made for change of diet. The diet remained the same during this interval as during the period immediately preceding. On February 15 the work period (digestion experiment No. 64) began, in which the diet was increased by about 900 calories of energy per day, and 2.5 grams of nitrogen. The subject neither gained nor lost body weight, but there was a storage of 0.78 gram of nitrogen per day during the three days of the test.

The duration of work with the friction machine and the amount measured during this period were as follows: February 15, three and one-sixth hours with 330,163 foot-pounds of work; February 16, three hours with 279,641 foot-pounds of work; February 17, three and one-half hours with 290,856 foot-pounds of work; February 18, two and one-half hours with 286,429 foot-pounds of work—a total for the four days of 1,187,088 foot-pounds or 163,736 kilogrammeters, the heat equivalent of which is 383 calories, or an average of 96 calories per day.

Table 10 gives the results of the digestion experiments.

*Details of experiment No. 4.*

*Subject.*—Chemist, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 63.10 kilograms (139.1 pounds); at end of first period, 62.83 kilograms; at beginning of second period, 63.05 kilograms; at end of second period, 62.74 kilograms; at beginning of third period, 62.69 kilograms; at end of third period and experiment, 62.69 kilograms (138.2 pounds).

The experiment commenced with breakfast February 8, 1898, and the first period continued two days. The second period commenced with breakfast February 11, and continued three days. The third period commenced with breakfast February 15, and continued four days.

*Table 10.—Results of experiment No. 4.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 62.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 306 | Codfish balls | 130 | 54 | 3.94 | 24 | 12 | 18 | 5 | 325 |
| 310 | Butter | 30 | 25 | .06 | ..... | 25 | ..... | 1 | 235 |
| 304 | Milk | 3,200 | 508 | 23.04 | 144 | 207 | 157 | 26 | 3,347 |
| 308 | Cracked corn (grits) | 60 | 53 | .89 | 6 | 1 | 46 | ..... | 228 |
| 307 | Oatmeal | 100 | 89 | 2.58 | 16 | 7 | 66 | 2 | 430 |
| 305 | Bread | 250 | 169 | 3.80 | 24 | 3 | 142 | 2 | 753 |
| ..... | Sugar | 80 | 80 | ..... | ..... | ..... | 80 | ..... | 317 |
| 309 | Potato chips | 50 | 47 | .58 | 4 | 16 | 27 | 2 | 276 |
| | Total | ..... | 1,025 | 34.89 | 218 | 271 | 536 | 38 | 5,911 |
| 311 | Feces | 65 | 48 | 2.87 | 18 | 8 | 22 | 17 | 269 |
| 313 | Urine | 2,070 | ..... | 27.12 | ..... | ..... | ..... | ..... | *a*250 |
| | Amount digested | ..... | 977 | 32.02 | 200 | 263 | 514 | 21 | 5,392 |
| | Coefficients of digestibility (per cent) | ..... | 95.3 | 91.7 | 91.7 | 97.0 | 95.9 | 55.3 | 91.2 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 63.*) | | | | | | | | |
| 306 | Codfish balls | 135 | 56 | 4.09 | 27 | 12 | 17 | 5 | 338 |
| 310 | Butter | 45 | 38 | .09 | 1 | 37 | ..... | 1 | 353 |
| 316 | Milk | 3,600 | 565 | 25.92 | 158 | 237 | 170 | 27 | 3,787 |
| 308 | Cracked corn (grits) | 90 | 79 | 1.34 | 8 | 1 | 70 | ..... | 342 |
| 307 | Oatmeal | 150 | 134 | 3.87 | 24 | 11 | 99 | 3 | 645 |
| 305 | Bread | 510 | 345 | 7.75 | 49 | 5 | 291 | 5 | 1,537 |
| ..... | Sugar | 100 | 100 | ..... | ..... | ..... | 100 | ..... | 396 |
| 309 | Potato chips | 75 | 70 | .86 | 5 | 24 | 41 | 3 | 414 |
| | Total | ..... | 1,387 | 43.92 | 272 | 327 | 788 | 44 | 7,812 |
| 317 | Feces | 56 | 41 | 2.22 | 14 | 8 | 19 | 15 | 271 |
| 320 | Urine | 2,867 | ..... | 39.81 | ..... | ..... | ..... | ..... | *a*323 |
| | Amount digested | ..... | 1,346 | 41.70 | 258 | 319 | 769 | 29 | 7,218 |
| | Coefficients of digestibility (per cent) | ..... | 97.0 | 94.8 | 94.8 | 97.5 | 97.6 | 65.9 | 92.4 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 64.*) | | | | | | | | |
| 323 | Codfish balls | 180 | 79 | 6.70 | 42 | 16 | 21 | 10 | 468 |
| 310 | Butter | 300 | 253 | .60 | 4 | 249 | ..... | 3 | 2,351 |
| 322 | Milk | 4,800 | 750 | 33.60 | 210 | 311 | 229 | 37 | 4,949 |
| 308 | Cracked corn (grits) | 120 | 106 | 1.79 | 11 | 2 | 93 | ..... | 456 |
| 307 | Oatmeal | 200 | 179 | 5.16 | 32 | 14 | 133 | 4 | 860 |
| 305 | Bread | 1,300 | 878 | 19.76 | 124 | 14 | 740 | 13 | 3,917 |
| ..... | Sugar | 130 | 130 | ..... | ..... | ..... | 130 | ..... | 515 |
| 309 | Potato chips | 100 | 94 | 1.15 | 7 | 33 | 54 | 4 | 552 |
| | Total | ..... | 2,469 | 68.76 | 430 | 639 | 1,400 | 71 | 14,068 |
| 324 | Feces | 97 | 75 | 4.18 | 26 | 14 | 35 | 22 | 505 |
| 327 | Urine | 3,966 | ..... | 61.45 | ..... | ..... | ..... | ..... | *a*505 |
| | Amount digested | ..... | 2,394 | 64.58 | 404 | 625 | 1,365 | 49 | 13,058 |
| | Coefficients of digestibility (per cent) | ..... | 97.0 | 93.9 | 93.9 | 97.8 | 97.5 | 69.0 | 92.8 |

*a* Estimated.

The urine for the two days of the first rest period amounted to 2,070 grams, and contained 1.3 per cent, or 27.12 grams, of nitrogen.

The urine was collected in portions corresponding to six-hour intervals during the second rest period, and the nitrogen determined by the usual method. The results are as follows:

TABLE 11.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 63).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 246 | 249 | 250 | 139 | 884 |
| Weight of nitrogen .....do.... | 3.12 | 3.36 | 3.43 | 2.38 | 12.29 |
| Per cent of nitrogen..... | 1.27 | 1.35 | 1.37 | 1.71 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 260 | 359 | 253 | 125 | 997 |
| Weight of nitrogen .....do.... | 3.22 | 3.88 | 3.85 | 2.40 | 13.35 |
| Per cent of nitrogen..... | 1.24 | 1.08 | 1.52 | 1.92 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 258 | 385 | 232 | 111 | 986 |
| Weight of nitrogen .....do.... | 3.69 | 4.50 | 4.06 | 1.92 | 14.17 |
| Per cent of nitrogen..... | 1.43 | 1.17 | 1.75 | 1.73 | ..... |

During the work period the urine was collected in portions corresponding to four equal intervals each day, beginning at 8 a. m., and the amount of nitrogen determined by the usual method. The results are as follows:

TABLE 12.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 64).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 307 | 305 | 192 | 171 | 975 |
| Weight of nitrogen .....do.... | 3.41 | 4.21 | 3.92 | 3.10 | 14.64 |
| Per cent of nitrogen..... | 1.11 | 1.38 | 2.04 | 1.81 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 307 | 294 | 259 | 138 | 998 |
| Weight of nitrogen .....do.... | 4.05 | 4.23 | 3.81 | 2.88 | 14.97 |
| Per cent of nitrogen..... | 1.32 | 1.44 | 1.47 | 2.09 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 339 | 302 | 275 | 172 | 1,088 |
| Weight of nitrogen .....do.... | 4.10 | 4.17 | 4.48 | 3.25 | 16.00 |
| Per cent of nitrogen..... | 1.21 | 1.38 | 1.63 | 1.89 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 257 | 348 | 229 | 71 | 905 |
| Weight of nitrogen .....do.... | 3.88 | 5.25 | 5.04 | 1.67 | 15.84 |
| Per cent of nitrogen..... | 1.51 | 1.51 | 2.20 | 2.35 | ..... |

The urine was collected for two periods of six hours each after the close of the experiment in order to give data for making any required allowance for nitrogen lag. The excretion of urine during the two periods ending at 8 p. m. amounted to 224 grams, with 1.75 per cent, or 3.88 grams, of nitrogen, and 243 grams with 1.87 per cent, or 4.06 grams, nitrogen respectively. The diet was not the same as during the experiment, but was such as the subject selected.

The average daily balance of income and outgo of nitrogen was calculated in the usual way from the data given in Tables 10 and 11. The results follow.

TABLE 13.—*Daily income and outgo of nitrogen in experiment No. 4.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 17.45 | 1.44 | 13.56 | 2.45 |
| Second period, rest, adjusted diet | 3 | 14.64 | .74 | 13.27 | .63 |
| Third period, work, diet increased 2.6 grams nitrogen and 913 calories | 4 | 17.19 | 1.05 | 15.36 | .78 |

## EXPERIMENT NO. 5.

This experiment was with the same subject as experiment No. 2. After the preliminary period, during which the proportion of the different food materials was selected, the first rest period (digestion experiment No. 65) began with breakfast February 8 and continued two days, during which the body weight of the subject remained the same, while there was a loss of 0.67 gram of nitrogen per day. During the following interval of two days the necessary analyses were completed and the second rest period (digestion experiment No. 66) began on February 11, with the same diet as the preceding period, with the addition of 67 grams of milk per day. During the three days of this experiment the subject lost 0.48 gram of nitrogen per day on the average, although the body weight remained the same. After an interval of one day the work period (digestion experiment No. 67) began with breakfast February 15 and continued for four days, as did the corresponding period in metabolism experiment No. 4. The diet was changed so as to increase the energy about 600 calories, and the nitrogen was thereby increased about 1 gram per day. There was a gain of 0.93 gram of nitrogen per day during the work period, or a relative gain of 1.41 grams as compared with the second rest period, although the nitrogen in the food was but 1 gram larger in amount. The body weight of the subject remained the same throughout the period of work with the friction machine. The duration of work and the amount measured on the various days of the period were as follows: February 15, three and one-sixth hours, with 293,870 foot-pounds of work; February 16, one hour, with 99,980 foot-pounds of work; February 17, three and one-fourth hours, with 220,630 foot-pounds of work; February 18, two and one-half hours, with 204,688 foot-pounds of work; a total of 819,168 foot-pounds, or 112,989 kilogrammeters, equivalent to 264 calories of energy during the four days, or an average of 66 calories per day.

The results of the digestion experiments follow:

*Details of experiment No. 5.*

*Subject.*—Chemist, 28 years of age.

*Weight (without clothing).*—At beginning of experiment, 66.91 kilograms (147.5 pounds); at end of first period, 66.91 kilograms; at beginning of second period, 66.77 kilograms; at end of second period, 66.77 kilograms; at beginning of third period,

66.46 kilograms; at end of third period and experiment, 66.46 kilograms (146.5 pounds).

The experiment commenced with breakfast February 8, 1898, and the first period continued two days. The second period commenced with breakfast February 11, and continued three days. The third period commenced with breakfast February 15, and continued four days.

TABLE 14.—*Results of experiment No. 5.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 65.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 306 | Codfish balls | 130 | 54 | 3.94 | 26 | 12 | 16 | 5 | 325 |
| 310 | Butter | 30 | 25 | .06 | ..... | 25 | ..... | 1 | 235 |
| 304 | Milk | 3,200 | 508 | 23.04 | 144 | 207 | 157 | 26 | 3,347 |
| 308 | Cracked corn (grits) | 100 | 88 | 1.49 | 9 | 1 | 78 | ..... | 380 |
| 307 | Oatmeal | 120 | 107 | 3.10 | 19 | 9 | 79 | 2 | 516 |
| 305 | Bread | 400 | 270 | 6.08 | 38 | 4 | 228 | 4 | 1,205 |
| ..... | Sugar | 100 | 100 | ..... | ..... | ..... | 100 | ..... | 396 |
| 309 | Potato chips | 40 | 37 | .46 | 3 | 13 | 21 | 1 | 221 |
| | Total | ..... | 1,189 | 38.17 | 239 | 271 | 679 | 39 | 6,625 |
| 312 | Feces | 56 | 41 | 2.60 | 16 | 9 | 16 | 15 | 306 |
| 313a | Urine | 1,942 | ..... | 36.90 | ..... | ..... | ..... | ..... | *a* 279 |
| | Amount available | ..... | 1,148 | 35.57 | 223 | 262 | 663 | 24 | 6,040 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 93.3 | 93.3 | 96.7 | 97.6 | 61.5 | 91.2 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 66.*) | | | | | | | | |
| 306 | Codfish balls | 162 | 68 | 4.91 | 32 | 15 | 21 | 7 | 405 |
| 310 | Butter | 45 | 38 | .09 | 1 | 37 | ..... | 1 | 353 |
| 316 | Milk | 5,000 | 785 | 36.00 | 219 | 330 | 236 | 38 | 5,260 |
| 308 | Cracked corn (grits) | 150 | 132 | 2.24 | 14 | 2 | 116 | 1 | 570 |
| 307 | Oatmeal | 180 | 161 | 4.64 | 29 | 13 | 119 | 3 | 774 |
| 305 | Bread | 600 | 405 | 9.12 | 57 | 6 | 342 | 6 | 1,808 |
| ..... | Sugar | 150 | 150 | ..... | ..... | ..... | 150 | ..... | 594 |
| 309 | Potato chips | 60 | 56 | .69 | 4 | 19 | 33 | 2 | 331 |
| | Total | ..... | 1,795 | 57.69 | 356 | 422 | 1,017 | 58 | 10,095 |
| 318 | Feces | 86 | 63 | 3.90 | 24 | 18 | 21 | 23 | 445 |
| 320a | Urine | 3,420 | ..... | 55.22 | ..... | ..... | ..... | ..... | *a* 415 |
| | Amount digested | ..... | 1,732 | 53.79 | 332 | 404 | 996 | 35 | 9,235 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 93.3 | 93.3 | 95.7 | 97.9 | 60.3 | 91.5 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 67.*) | | | | | | | | |
| 323 | Codfish balls | 216 | 95 | 5.88 | 51 | 19 | 25 | 11 | 562 |
| 310 | Butter | 200 | 169 | .40 | 3 | 166 | ..... | 4 | 1,567 |
| 322 | Milk | 6,700 | 1,047 | 46.90 | 293 | 434 | 320 | 52 | 6,908 |
| 308 | Cracked corn (grits) | 200 | 176 | 2.98 | 19 | 2 | 155 | 1 | 760 |
| 307 | Oatmeal | 240 | 215 | 6.19 | 39 | 17 | 159 | 5 | 1,032 |
| 305 | Bread | 1,200 | 811 | 18.12 | 114 | 13 | 684 | 12 | 3,616 |
| ..... | Sugar | 200 | 200 | ..... | ..... | ..... | 200 | ..... | 794 |
| 309 | Potato chips | 80 | 75 | .92 | 6 | 26 | 43 | 3 | 441 |
| | Total | ..... | 2,788 | 81.39 | 525 | 677 | 1,586 | 88 | 15,680 |
| 325 | Feces | 137 | 103 | 6.43 | 40 | 37 | 26 | 34 | 732 |
| 327a | Urine | 3,905 | ..... | 71.25 | ..... | ..... | ..... | ..... | *a* 606 |
| | Amount digested | ..... | 2,685 | 74.96 | 485 | 640 | 1,560 | 54 | 14,342 |
| | Coefficients of digestibility (per cent) | ..... | 93.3 | 92.4 | 92.4 | 94.5 | 98.4 | 61.4 | 91.5 |

*a* Estimated.

During the two days of the first rest period 1,942 grams of urine were eliminated, containing 1.90 per cent, or 36.90 grams nitrogen.

The amount of urine and its content of nitrogen for each portion corresponding to six-hour intervals during the second rest period are shown in the following table:

TABLE 15.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 66).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 197 | 239 | 222 | 246 | 904 |
| Weight of nitrogen .....do.... | 3.94 | 5.16 | 4.80 | 4.35 | 18.25 |
| Per cent of nitrogen..... | 2.00 | 2.16 | 2.16 | 1.77 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 195 | 254 | 310 | 280 | 1,039 |
| Weight of nitrogen .....do.... | 4.17 | 5.82 | 5.80 | 4.40 | 20.19 |
| Per cent of nitrogen..... | 2.14 | 2.29 | 1.87 | 1.57 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 230 | 333 | 312 | 116 | 991 |
| Weight of nitrogen .....do.... | 4.07 | 5.93 | 4.99 | 1.79 | 16.78 |
| Per cent of nitrogen..... | 1.77 | 1.78 | 1.60 | 1.54 | ..... |

There was an elimination of 486 grams of urine, with 1.28 per cent or 6.22 grams of nitrogen during the six hours immediately following the close of the experiment.

The urine was, as usual, collected in portions corresponding to six-hour intervals during the third or work period. The quantity eliminated and its content of nitrogen are shown in the following table:

TABLE 16.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 67).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 208 | 221 | 229 | 236 | 894 |
| Weight of nitrogen .....do.... | 3.06 | 4.51 | 4.53 | 4.01 | 16.11 |
| Per cent of nitrogen..... | 1.47 | 2.04 | 1.98 | 1.70 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 256 | 287 | 270 | 220 | 1,033 |
| Weight of nitrogen .....do.... | 4.07 | 4.82 | 5.56 | 3.98 | 18.43 |
| Per cent of nitrogen..... | 1.59 | 1.68 | 2.06 | 1.81 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 297 | 221 | 265 | 175 | 958 |
| Weight of nitrogen .....do.... | 4.40 | 4.27 | 5.91 | 3.19 | 17.77 |
| Per cent of nitrogen..... | 1.48 | 1.93 | 2.23 | 1.82 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 235 | 284 | 257 | 244 | 1,020 |
| Weight of nitrogen .....do.... | 3.90 | 5.40 | 5.17 | 4.47 | 18.94 |
| Per cent of nitrogen..... | 1.66 | 1.90 | 2.01 | 1.83 | ..... |

During the two periods of six hours each immediately following this experiment the urine amounted to 263 grams with 1.85 per cent or 4.81 grams nitrogen and 326 grams with 1.69 per cent or 5.51 grams, respectively.

The above data regarding the income of nitrogen in the food and the excretion of nitrogen in the feces and urine serve for computing the average daily balance of income and outgo of this element. The effects of muscular work on the excretion of nitrogen is discussed when the experiments are considered as a whole.

The nitrogen balance follows:

TABLE 17.—*Daily income and outgo of nitrogen in experiment No. 5.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 19.08 | 1.30 | 18.45 | −0.67 |
| Second period, rest, adjusted diet | 3 | 19.23 | 1.30 | 18.41 | − .48 |
| Third period, work, diet increased 1.1 grams nitrogen and 555 calories | 4 | 20.35 | 1.61 | 17.81 | + .93 |

## EXPERIMENT NO. 6.

This experiment, which was carried on with the same subject as experiment No. 3, was begun at the same time as experiments Nos. 4 and 5, but the first rest period had to be given up owing to a slight indisposition of the subject. The experiment was resumed at the beginning of the second rest period, February 11. This period (digestion experiment No. 68) continued three days, during which time the subject apparently lost 0.28 kilogram in body weight and 0.41 gram of nitrogen per day. After the usual interval of one day following this period the work period (digestion experiment No. 69) began with breakfast February 15, and continued four days. The diet was increased by the addition of about 700 calories of energy per day and about 1 gram of nitrogen. The body weight of the subject remained nearly the same during the work period, while there was a gain of 0.64 gram of nitrogen per day. The duration of work with the friction machine and the amount measured during the four days of the work period were as follows: February 15, three hours, with 251,615 foot-pounds of work; February 16, two and one-half hours, with 276,948 foot-pounds of work; February 17, three hours, with 288,161 foot-pounds of work; February 18, three and one-fourth hours, with 353,571 foot-pounds of work, a total of 1,170,295 foot-pounds or 161,420 kilogrammeters of work, the heat equivalent of which is 378 calories, or an average of 95 calories per day.

The statistics of the digestion experiment in the different periods are shown in Table 18.

*Details of experiment No. 6.*

*Subject.*—Chemist, 29 years of age.

*Weight (without clothing).*—At beginning of experiment, 59.02 kilograms (130.1 pounds); at end of first period, 58.74 kilograms; at beginning of second period, 59.33 kilograms; at end of second period and experiment, 59.24 kilograms (130.6 pounds).

The experiment commenced with breakfast February 11, 1898, and the first period continued three days. The second period commenced with breakfast February 15 and continued four days.

TABLE 18.—*Results of experiment No. 6.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (Discontinued on account of indisposition of subject.) | | | | | | | | |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 68.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 306 | Codfish balls | 139 | 58 | 4.21 | 28 | 12 | 18 | 2 | 348 |
| 310 | Butter | 45 | 38 | .09 | 1 | 37 | ..... | 1 | 353 |
| 316 | Milk | 3,600 | 565 | 25.92 | 158 | 237 | 170 | 27 | 3,787 |
| 308 | Cracked corn (grits) | 180 | 158 | 2.68 | 16 | 2 | 140 | 1 | 684 |
| 307 | Oatmeal | 150 | 134 | 3.87 | 24 | 11 | 99 | 3 | 645 |
| 305 | Bread | 210 | 142 | 3.19 | 20 | 2 | 120 | 2 | 633 |
| ..... | Sugar | 195 | 195 | ..... | ..... | ..... | 195 | ..... | 772 |
| | Total | ..... | 1,290 | 39.96 | 247 | 301 | 742 | 36 | 7,222 |
| 319 | Feces | 61 | 47 | 1.87 | 12 | 10 | 25 | 15 | 347 |
| 320b | Urine | 2,873 | ..... | 39.33 | ..... | ..... | ..... | ..... | *a* 294 |
| | Amount digested | ..... | 1,243 | 38.09 | 235 | 291 | 717 | 21 | 6,581 |
| | Coefficients of digestibility (per cent) | ..... | 96.4 | 95.1 | 95.1 | 96.7 | 96.6 | 58.3 | 91.1 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 69.*) | | | | | | | | |
| 323 | Codfish balls | 184 | 81 | 6.84 | 43 | 16 | 22 | 10 | 479 |
| 310 | Butter | 300 | 253 | .60 | 4 | 249 | ..... | 7 | 2,351 |
| 322 | Milk | 4,800 | 750 | 33.60 | 210 | 311 | 229 | 37 | 4,949 |
| 308 | Grits | 425 | 374 | 6.33 | 40 | 5 | 329 | 2 | 1,616 |
| 307 | Oatmeal | 210 | 188 | 5.42 | 34 | 15 | 139 | 4 | 903 |
| 305 | Bread | 350 | 236 | 5.32 | 33 | 4 | 199 | 3 | 1,055 |
| ..... | Sugar | 290 | 290 | ..... | ..... | ..... | 290 | ..... | 1,148 |
| | Total | ..... | 2,172 | 58.11 | 364 | 600 | 1,208 | 63 | 12,501 |
| 326 | Feces | 94 | 73 | 3.22 | 20 | 14 | 39 | 21 | 569 |
| 327b | Urine | 3,987 | ..... | 52.32 | ..... | ..... | ..... | ..... | *a* 430 |
| | Amount digested | ..... | 2,099 | 54.89 | 344 | 586 | 1,169 | 42 | 11,502 |
| | Coefficients of digestibility (per cent) | ..... | 94.6 | 96.5 | 94.5 | 97.7 | 96.8 | 66.7 | 92.0 |

*a* Estimated.

As previously stated, the subject was not well for a short time, and the first rest period had to be discontinued.

Table 19 shows the average daily outgo of nitrogen in the urine in the second rest period, which appeared to be entirely normal.

TABLE 19.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 68).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 111 | 142 | 608 | | 861 |
| Weight of nitrogen .....do.... | 2.15 | 3.04 | 7.78 | | 12.97 |
| Per cent of nitrogen..... | 1.94 | 2.14 | 1.28 | | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 158 | 188 | 532 | | 878 |
| Weight of nitrogen .....do.... | 2.46 | 3.38 | 7.39 | | 13.23 |
| Per cent of nitrogen..... | 1.56 | 1.80 | 1.39 | | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 192 | 521 | 421 | | 1,134 |
| Weight of nitrogen .....do.... | 2.80 | 3.80 | 6.53 | | 13.13 |
| Per cent of nitrogen..... | 1.46 | .73 | 1.55 | | ..... |

The elimination of nitrogen during the third or work period is shown in the following table. The urine, as a rule, was collected in portions corresponding to six-hour intervals.

TABLE 20.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 69).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 155 | 192 | 620 | | 967 |
| Weight of nitrogen .....do.... | 2.59 | 2.90 | 6.76 | | 12.25 |
| Per cent of nitrogen..... | 1.67 | 1.51 | 1.09 | | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 234 | 320 | 387 | 198 | 1,139 |
| Weight of nitrogen .....do.... | 2.64 | 3.87 | 3.83 | 2.69 | 13.03 |
| Per cent of nitrogen..... | 1.13 | 1.21 | .99 | 1.36 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 218 | 218 | 536 | | 972 |
| Weight of nitrogen .....do.... | 2.62 | 3.29 | 7.45 | | 13.36 |
| Per cent of nitrogen..... | 1.20 | 1.51 | 1.39 | | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 210 | 227 | 309 | 163 | 909 |
| Weight of nitrogen .....do.... | 2.86 | 3.50 | 4.39 | 2.93 | 13.68 |
| Per cent of nitrogen..... | 1.36 | 1.54 | 1.42 | 1.80 | ..... |

Between the hours 8 a. m. and 2 p. m. following the close of the experiment 199 grams of urine was eliminated, containing 1.39 per cent, or 2.77 grams, nitrogen. The corresponding amounts during the second six-hour period following the experiment were 229 grams, 1.63 per cent, and 3.73 grams, respectively.

The daily balance of income and outgo of nitrogen during the different periods of the experiment was computed in the usual manner, and the results are shown below:

TABLE 21.—*Daily income and outgo of nitrogen in experiment No. 6.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| First period—rest, trial diet. Discontinued on account of indisposition of subject. | *Days.* | *Grams.* | *Gram.* | *Grams.* | *Gram.* |
| Second period—rest, adjusted diet ..... | 3 | 13.32 | 0.62 | 13.11 | −0.41 |
| Third period—work, diet increased 1.2 grams nitrogen and 727 calories. ..... | 1 | 14.53 | .81 | 13.08 | + .64 |

## EXPERIMENT NO. 7.

After the analytical details of the second series of experiments had been completed and most of the results computed, a third series was begun upon two of the subjects who served in the preceding tests. In order to give variety to the diet, boiled eggs were added to the menu and a jelly made from a commercial gelatin preparation was used in place of the corn grits. Canned corned beef was also substituted for the fresh beef used to make the beef loaf. Much of the visible fat of the canned beef was rejected. The lean meat was passed through a meat cutter and carefully sampled. Potted ham was also added to the diet to give variety. This was served without further preparation. Experiment No. 7 was made with the same subject as experiments Nos. 1 and 4. After the usual preliminary period, during which the proportions of the different kinds of food materials were selected, the first rest period (digestion experiment No. 70) began with breakfast March 31, 1898, and continued two days, as usual. The subject apparently lost 0.41 kilogram in body weight during this time, but there was a large gain of nitrogen, amounting to 6.57 grams per day. At the close of the usual interval between the first and second rest periods the diet was reduced by 60 grams of potted ham and 600 grams of milk per day. The second rest period (digestion experiment No. 71) began with breakfast April 3, and continued two days. The subject was practically in nitrogen equilibrium. For the work period the diet was increased by the addition of fats and carbohydrates, so as to furnish between 500 and 600 additional calories of energy per day. There was little change in the amount of nitrogen. The subject performed the usual amount of work with the friction machine on each of the three days of the period. The duration and amount measured on each day was as follows: April 7, four hours of work, with 453,871 foot-pounds of work; April 8, two and three-fourth hours, with 338,100 foot-pounds of work; April 9, two hours, with 231,000 foot-pounds of work; a total of 1,022,971 foot-pounds, or 141,100 kilogrammeters, the heat equivalent of which is 393 calories, or an average of 131 calories per day. There was a daily gain of about 0.9 gram of nitrogen during the period.

The following table gives the results of the digestion experiments in the several periods:

*Details of experiment No. 7.*

*Subject.*—Chemist, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 62.55 kilograms (137.9 pounds); at end of first period, 62.14 kilograms; at beginning of second period, 62.83 kilograms; at end of second period, 62.69 kilograms; at beginning of third period, 62.60 kilograms; at end of third period and experiment, 62.83 kilograms (138.5 pounds).

The experiment commenced with breakfast March 31, 1898, and the first period

continued two days. The second period commenced with breakfast April 3, and continued two days. The third period commenced with breakfast April 7, and continued three days.

TABLE 22.—*Results of experiment No. 7.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 70.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 332 | Canned corned beef | 64 | 26 | 2.43 | 15 | 11 | ..... | 3 | 188 |
| 331 | Potted ham | 120 | 58 | 3.68 | 23 | 35 | ..... | 5 | 446 |
| 333 | Eggs | 518 | 128 | 11.60 | 72 | 56 | ..... | 5 | 939 |
| 335 | Butter | 40 | 30 | .08 | 1 | 29 | ..... | 3 | 283 |
| 328 | Milk | 4,200 | 666 | 30.24 | 189 | 277 | 200 | 33 | 4,473 |
| 334 | Gelatin preparation | 42 | 41 | .37 | 2 | ..... | 39 | ..... | 165 |
| 329 | Oatmeal | 120 | 109 | 2.95 | 18 | 9 | 82 | 2 | 515 |
| 330 | Bread | 423 | 293 | 6.09 | 38 | 5 | 250 | 4 | 1,282 |
| ..... | Sugar | 60 | 60 | ..... | ..... | ..... | 60 | ..... | 238 |
| | Total | ..... | 1,411 | 57.44 | 358 | 422 | 631 | 55 | 8,529 |
| 336 | Feces | 62 | 45 | 2.28 | 14 | 11 | 20 | 17 | 317 |
| 338 | Urine | 4,002 | ..... | 42.02 | ..... | ..... | ..... | ..... | *a* 430 |
| | Amount digested | ..... | 1,366 | 55.16 | 344 | 411 | 611 | 38 | 7,782 |
| | Coefficients of digestibility (per cent) | ..... | 96.8 | 96.1 | 96.1 | 97.4 | 96.8 | 69.1 | 91.2 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 71.*) | | | | | | | | |
| 332 | Canned corned beef | 64 | 26 | 2.43 | 15 | 11 | ..... | 3 | 188 |
| 333 | Eggs | 520 | 129 | 11.65 | 73 | 56 | ..... | 5 | 943 |
| 335 | Butter | 40 | 30 | .08 | 1 | 29 | ..... | 3 | 283 |
| 339 | Milk | 3,000 | 479 | 21.30 | 133 | 194 | 152 | 23 | 3,270 |
| 334 | Gelatin preparation | 87 | 86 | .77 | 5 | 1 | 80 | ..... | 342 |
| 329 | Oatmeal | 120 | 109 | 2.95 | 18 | 9 | 82 | 2 | 515 |
| 330 | Bread | 418 | 289 | 6.09 | 37 | 5 | 247 | 4 | 1,267 |
| ..... | Sugar | 60 | 60 | ..... | ..... | ..... | 60 | ..... | 238 |
| | Total | ..... | 1,208 | 45.27 | 282 | 305 | 621 | 40 | 7,046 |
| 340 | Feces | 57 | 42 | 1.92 | 12 | 11 | 19 | 15 | 310 |
| 342 | Urine | 2,755 | ..... | 42.70 | ..... | ..... | ..... | ..... | *a* 339 |
| | Amount digested | ..... | 1,166 | 43.35 | 270 | 294 | 602 | 25 | 6,397 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 95.7 | 95.7 | 96.4 | 96.9 | 62.5 | 90.8 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN NITROGEN AND ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 72.*) | | | | | | | | |
| 332 | Canned corned beef | 96 | 39 | 3.65 | 23 | 16 | ..... | 4 | 282 |
| 333 | Eggs | 759 | 188 | 17.00 | 106 | 82 | ..... | 7 | 1,376 |
| 335 | Butter | 200 | 151 | .40 | 3 | 148 | ..... | 17 | 1,415 |
| 343 | Milk | 4,500 | 707 | 30.60 | 191 | 286 | 230 | 35 | 4,784 |
| 334 | Gelatin preparation | 193 | 190 | 1.72 | 11 | 1 | 178 | ..... | 758 |
| 329 | Oatmeal | 180 | 164 | 4.43 | 28 | 13 | 123 | 4 | 773 |
| 330 | Bread | 824 | 570 | 11.87 | 74 | 9 | 487 | 8 | 2,496 |
| ..... | Sugar | 90 | 90 | ..... | ..... | ..... | 90 | ..... | 358 |
| | Total | ..... | 2,099 | 69.67 | 436 | 555 | 1,108 | 75 | 12,242 |
| 344 | Feces | 79 | 58 | 2.65 | 17 | 14 | 27 | 21 | 438 |
| 346 | Urine | 4,014 | ..... | 64.43 | ..... | ..... | ..... | ..... | *a* 525 |
| | Amount digested | ..... | 2,041 | 67.02 | 419 | 541 | 1,081 | 54 | 11,279 |
| | Coefficients of digestibility (per cent) | ..... | 97.2 | 96.1 | 96.1 | 97.5 | 97.6 | 72.0 | 92.1 |

*a* Estimated.

The total urine for the first rest period amounted to 4.002 grams, with 1.05 per cent or 42.02 grams nitrogen.

The urine was also collected in one composite sample for the second rest period and amounted to 2.755 grams, containing 1.55 per cent or 42.70 grams nitrogen.

As usual the urine was collected in six-hour portions during the third or work period and the amount of nitrogen determined. The results are as follows:

TABLE 23.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 72).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 338 | 531 | 278 | 237 | 1,384 |
| Weight of nitrogen .....do.... | 4.66 | 7.70 | 5.17 | 4.50 | 22.03 |
| Per cent of nitrogen..... ..... | 1.38 | 1.45 | 1.86 | 1.90 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 394 | 429 | 307 | 281 | 1,411 |
| Weight of nitrogen .....do.... | 5.44 | 5.66 | 5.86 | 4.52 | 21.48 |
| Per cent of nitrogen..... | 1.38 | 1.32 | 1.91 | 1.61 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 275 | 452 | 308 | 184 | 1,219 |
| Weight of nitrogen .....do.... | 4.40 | 6.51 | 5.76 | 4.25 | 20.92 |
| Per cent of nitrogen..... | 1.60 | 1.44 | 1.87 | 2.31 | ..... |

From 8 a. m. to 2 p. m. on the day following the close of this experiment 340 grams of urine containing 1.37 per cent or 4.66 grams nitrogen was eliminated, while from 2 p. m. to 8 p. m. the urine amounted to 418 grams with 1.35 per cent or 5.64 grams nitrogen. The diet was not the same after the close of the experiment as during the third period.

Following the usual method the average daily balance of income and outgo of nitrogen was calculated as follows:

TABLE 24.—*Daily income and outgo of nitrogen in experiment No. 7.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet..... | 2 | 28.72 | 1.14 | 21.01 | 6.57 |
| Second period, rest, adjusted diet..... | 2 | 22.64 | .96 | 21.35 | .33 |
| Third period, work, diet increased 558 calories ..... | 3 | 23.22 | .88 | 21.48 | .86 |

## EXPERIMENT NO. 8.

Experiment No. 8, which was the last of the series of 1898, was carried on simultaneously with experiment No. 7. The subject was the same as in experiments Nos. 2 and 5 above described. The statistics of the digestion experiments are shown in Table 25. During the first rest period (digestion experiment No. 73) the subject gained 1.44 grams of nitrogen per day. The diet was therefore reduced by 60 grams of potted ham and 122 grams of milk per day during the two days of the

second rest period (digestion experiment No. 74). There was, however, still a gain of nitrogen amounting to 0.87 gram per day. The third or work period (digestion experiment No. 74) began with breakfast April 7 and continued three days. The diet was increased by the addition of fats and carbohydrates sufficient to furnish between 400 and 500 calories of energy per day above that in the preceding period, while the amount of nitrogen was not greatly changed. There was an apparent gain of 0.45 kilogram in body weight during the three days and a daily storage of 2.37 grams of nitrogen. The duration of work with the friction machine and the amount measured on the successive days of the third period were as follows: April 7, four hours, with 468,531 foot-pounds of work; April 8, one and one-half hours, with 222,600 foot-pounds of work; April 9, two and one-third hours, with 333,900 foot-pounds of work—a total of 1,025,031 foot-pounds or 141,384 kilogrammeters, the heat equivalent of which is 531 calories or an average of 110 calories per day.

*Details of experiment No. 8.*

*Subject.*—Chemist, 28 years of age.

*Weight (without clothing).*—At beginning of experiment, 67.45 kilograms (148.7 pounds); at end of first period, 67.36 kilograms; at beginning of second period, 67.36 kilograms; at end of second period, 67.36 kilograms; at beginning of third period, 66.46 kilograms; at end of third period and experiment, 66.91 kilograms (147.5 pounds).

The experiment commenced with breakfast March 31, 1898, and the first period continued two days. The second period commenced with breakfast April 3 and continued two days. The third period commenced with breakfast April 7 and continued three days.

TABLE 25.—*Results of experiment No. 8.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 73.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 332 | Canned corned beef | 64 | 26 | 2.43 | 15 | 11 | ..... | 3 | 188 |
| 331 | Potted ham | 120 | 58 | 3.68 | 23 | 35 | ..... | 5 | 446 |
| 333 | Eggs | 525 | 130 | 11.76 | 74 | 56 | ..... | 5 | 952 |
| 335 | Butter | 5 | 4 | .01 | ..... | 4 | ..... | ..... | 35 |
| 328 | Milk | 4,000 | 634 | 28.80 | 180 | 264 | 190 | 31 | 4,260 |
| 334 | Gelatin preparation | 42 | 41 | .37 | 2 | ..... | 39 | ..... | 165 |
| 329 | Oatmeal | 120 | 109 | 2.95 | 18 | 9 | 82 | 2 | 515 |
| 330 | Bread | 325 | 225 | 4.68 | 29 | 4 | 192 | 3 | 985 |
| ..... | Sugar | 60 | 60 | ..... | ..... | ..... | 60 | ..... | 238 |
| | Total | ..... | 1,287 | 54.68 | 341 | 383 | 563 | 49 | 7,784 |
| 337 | Feces | 64 | 45 | 2.61 | 16 | 18 | 11 | 19 | 329 |
| 338a | Urine | 2,982 | ..... | 49.20 | ..... | ..... | ..... | ..... | a406 |
| | Amount digested | ..... | 1,242 | 52.07 | 325 | 365 | 552 | 30 | 7,049 |
| | Coefficients of digestibility (per cent) | ..... | 96.5 | 95.3 | 95.3 | 95.3 | 98.0 | 61.2 | 90.6 |

a Estimated.

TABLE 25.—*Results of experiment No. 8*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | SECOND PERIOD. DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. (*Digestion experiment No. 74.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 332 | Canned corned beef | 64 | 26 | 2.43 | 15 | 11 | ..... | 3 | 188 |
| 333 | Eggs | 524 | 130 | 11.74 | 74 | 56 | ..... | 5 | 950 |
| 335 | Butter | 5 | 4 | .01 | ..... | 4 | ..... | ..... | 35 |
| 339 | Milk | 4,244 | 677 | 30.13 | 189 | 274 | 214 | 33 | 4,626 |
| 334 | Gelatin preparation | 87 | 86 | .77 | 5 | 1 | 80 | ..... | 342 |
| 329 | Oatmeal | 120 | 109 | 2.95 | 18 | 9 | 82 | 2 | 515 |
| 330 | Bread | 325 | 225 | 4.68 | 29 | 4 | 192 | 3 | 985 |
| ..... | Sugar | 60 | 60 | ..... | ..... | ..... | 60 | ..... | 238 |
| | Total | ..... | 1,317 | 52.71 | 330 | 359 | 628 | 46 | 7,879 |
| 341 | Feces | 74 | 54 | 2.95 | 18 | 16 | 20 | 20 | 409 |
| 342a | Urine | 2,698 | ..... | 48.02 | ..... | ..... | ..... | ..... | *a* 390 |
| | Amount digested | ..... | 1,263 | 49.76 | 312 | 343 | 608 | 26 | 7,080 |
| | Coefficients of digestibility (per cent) | ..... | 95.9 | 94.5 | 94.5 | 95.5 | 96.8 | 56.5 | 89.9 |
| | THIRD PERIOD. DIET INCREASED IN NITROGEN AND ENERGY. WORK. (*Digestion experiment No. 75.*) | | | | | | | | |
| 332 | Canned corned beef | 96 | 39 | 3.65 | 23 | 16 | ..... | 4 | 282 |
| 333 | Eggs | 776 | 192 | 17.38 | 109 | 83 | ..... | 8 | 1,407 |
| 335 | Butter | 115 | 86 | .23 | 1 | 85 | ..... | 10 | 813 |
| 343 | Milk | 6,400 | 1,006 | 43.52 | 272 | 407 | 327 | 49 | 6,803 |
| 334 | Gelatin preparation | 193 | 190 | 1.72 | 11 | 1 | 178 | ..... | 758 |
| 329 | Oatmeal | 180 | 164 | 4.43 | 28 | 13 | 123 | 4 | 773 |
| 330 | Bread | 671 | 464 | 9.66 | 60 | 8 | 396 | 7 | 2,034 |
| ..... | Sugar | 90 | 90 | ..... | ..... | ..... | 90 | ..... | 356 |
| | Total | ..... | 2,231 | 80.59 | 504 | 613 | 1,114 | 82 | 13,226 |
| 345 | Feces | 113 | 82 | 4.45 | 28 | 29 | 25 | 31 | 601 |
| 346a | Urine | 3,346 | ..... | 69.03 | ..... | ..... | ..... | ..... | *a* 595 |
| | Amount digested | ..... | 2,149 | 76.14 | 476 | 584 | 1,089 | 51 | 12,030 |
| | Coefficients of digestibility (per cent) | ..... | 96.3 | 94.4 | 94.4 | 95.3 | 97.8 | 62.2 | 91.0 |

*a* Estimated.

During the first rest period there was a total elimination of 2,982 grams of urine containing 1.65 per cent or 49.20 grams nitrogen.

The total urine for the second rest period amounted to 2,698 grams, containing 1.78 per cent or 48.02 grams nitrogen.

The outgo of nitrogen in the urine determined in portions corresponding to six-hour intervals during the third or work period was as follows:

TABLE 26.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 75).*

| | 8 a. m to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 250 | 266 | 236 | 288 | 1,040 |
| Weight of nitrogen .....do.... | 4.80 | 5.43 | 5.45 | 5.47 | 21.15 |
| Per cent of nitrogen..... | 1.92 | 2.04 | 2.31 | 1.90 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 236 | 316 | 303 | 248 | 1,103 |
| Weight of nitrogen .....do.... | 4.77 | 6.83 | 6.67 | 4.56 | 22.83 |
| Per cent of nitrogen..... | 2.02 | 2.16 | 2.20 | 1.84 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 281 | 323 | 357 | 242 | 1,203 |
| Weight of nitrogen .....do.... | 5.48 | 6.94 | 7.98 | 4.67 | 25.05 |
| Per cent of nitrogen..... | 1.95 | 2.15 | 2.23 | 1.93 | ..... |

The urine was collected for two periods of six hours each after the close of the experiment and the nitrogen determined. The results are as follows: 8 a. m. to 2 p. m., 350 grams urine with 1.78 per cent or 6.23 grams nitrogen; 2 p. m. to 8 p. m., 403 grams urine with 1.70 per cent or 6.85 grams nitrogen. The experimental diet was not continued after the close of the experiment.

Table 27 shows the average daily balance of income and outgo of nitrogen, which was calculated for the three periods from the data included above.

TABLE 27.—*Daily income and outgo of nitrogen in experiment No. 8.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet..... | 2 | 27.34 | 1.30 | 24.60 | 1.44 |
| Second period, rest, adjusted diet..... | 3 | 26.36 | 1.48 | 24.01 | .87 |
| Third period, work, diet increased 468 calories..... | 3 | 26.86 | 1.48 | 23.01 | 2.37 |

## SUMMARY OF RESULTS OBTAINED IN 1897–98.

Inasmuch as the methods followed in conducting the two series of digestion experiments in 1898 and 1899 were the same, and as the influence of muscular work on digestibility can be more satisfactorily discussed when all the experiments available are considered, this phase of the work of 1898 is spoken of later in connection with that of 1899.

The method of conducting the nitrogen metabolism experiments varied somewhat in the two series and therefore this portion of each year's work is briefly discussed separately. The results of the two years are also compared and discussed (p. 75).

## INCOME AND OUTGO OF NITROGEN.

The results of observations on metabolism made in the foregoing experiments (Nos. 1–8) are briefly summarized in Table 28, which shows the income and outgo of nitrogen and in addition the total and available energy in each period and the amount of external muscular work actually measured during the work periods.

TABLE 28.—*Daily income and outgo of nitrogen and energy in metabolism experiments Nos. 1–8, with work actually measured.*

| Metabolism experiment number. | Digestion experiment number. | Character of experiment. | Subject. | Average gain (+) or loss (−) in body weight. | Nitrogen. | | | | Energy. | | | | Measured work. *a* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | In food. | In feces. | In urine. | Gain (+), loss (−). | In food. | In feces. | In urine. | Available. | Amount. | Heat equivalent. |
| | | | | *Kg.* | *Grams.* | *Grms.* | *Grams.* | *Grams.* | *Calories.* | *Calories.* | *Calories.* | *Calories.* | *Kgs.* | *Calories.* |
| 1 | 53 | Rest ... | A. | −0.36 | 21.32 | 1.21 | 15.98 | +4.13 | 3,801 | 192 | 158 | 3,451 | ..... | ..... |
| | 54 | ....do .. | A. | −0.14 | 17.70 | .89 | 15.48 | +1.33 | 3,109 | 160 | 131 | 2,818 | ..... | ..... |
| | 55 | Work .. | A. | 0 | 20.79 | .79 | 16.29 | +3.71 | 4,016 | 149 | 156 | 3,711 | 24,005 | 56 |
| 2 | 56 | Rest ... | B. | −0.09 | 22.23 | 1.32 | 20.80 | + .11 | 3,444 | 154 | 164 | 3,126 | ..... | ..... |
| | 57 | ....do .. | B. | −0.32 | 23.13 | 1.29 | 20.52 | +1.32 | 3,397 | 139 | 170 | 3,088 | ..... | ..... |
| | 58 | Work .. | B. | −0.63 | 25.92 | 1.38 | 20.41 | +4.13 | 4,338 | 166 | 192 | 3,980 | 18,221 | 43 |
| 3 | 59 | Rest ... | C. | +0.36 | 23.44 | 1.38 | 15.71 | +6.35 | 3,599 | 218 | 183 | 3,198 | ..... | ..... |
| | 60 | ....do .. | C. | −0.54 | 17.46 | .92 | 15.00 | +1.54 | 2,551 | 122 | 129 | 2,300 | ..... | ..... |
| | 61 | Work .. | C. | −0.63 | 20.55 | 1.36 | 15.20 | +4.09 | 3,348 | 187 | 110 | 3,051 | 23,480 | 55 |
| 4 | 62 | Rest ... | A. | −0.27 | 17.45 | 1.44 | 13.56 | +2.45 | 2,956 | 135 | 125 | 2,696 | ..... | ..... |
| | 63 | ....do .. | A. | −0.32 | 14.64 | .74 | 13.27 | + .63 | 2,604 | 90 | 108 | 2,406 | ..... | ..... |
| | 64 | Work .. | A. | −0.05 | 17.19 | 1.05 | 15.36 | + .78 | 3,517 | 126 | 126 | 3,265 | 40,934 | 96 |
| 5 | 65 | Rest ... | B. | 0 | 19.08 | 1.30 | 18.45 | − .67 | 3,313 | 153 | 140 | 3,020 | ..... | ..... |
| | 66 | ....do .. | B. | 0 | 19.23 | 1.30 | 18.41 | − .48 | 3,365 | 148 | 138 | 3,079 | ..... | ..... |
| | 67 | Work .. | B. | 0 | 20.35 | 1.61 | 17.81 | + .93 | 3,920 | 183 | 151 | 3,586 | 28,247 | 66 |
| 6 | 68 | Rest ... | C. | −0.27 | 13.32 | .62 | 13.11 | − .41 | 2,407 | 116 | 98 | 2,193 | ..... | ..... |
| | 69 | Work .. | C. | −0.09 | 14.53 | .81 | 13.08 | + .64 | 3,134 | 142 | 107 | 2,875 | 40,355 | 95 |
| 7 | 70 | Rest ... | A. | −0.41 | 28.72 | 1.14 | 21.01 | +6.57 | 4,264 | 158 | 215 | 3,891 | ..... | ..... |
| | 71 | ....do .. | A. | −0.14 | 22.64 | .96 | 21.35 | + .33 | 3,523 | 155 | 169 | 3,199 | ..... | ..... |
| | 72 | Work .. | A. | +0.23 | 23.22 | .88 | 21.48 | + .86 | 4,081 | 146 | 175 | 3,760 | 47,033 | 110 |
| 8 | 73 | Rest ... | B. | −0.09 | 27.34 | 1.30 | 24.60 | +1.44 | 3,892 | 164 | 203 | 3,525 | ..... | ..... |
| | 74 | ....do .. | B. | 0 | 26.36 | 1.48 | 24.01 | + .87 | 3,940 | 205 | 195 | 3,540 | ..... | ..... |
| | 75 | Work .. | B. | +0.45 | 26.86 | 1.48 | 23.01 | +2.37 | 4,408 | 200 | 198 | 4,010 | 47,128 | 110 |
| | Average, first rest ..... | | | | 21.61 | 1.21 | 17.90 | +2.50 | 3,460 | 161 | 161 | 3,137 | ..... | ..... |
| | Average, second rest ..... | | | | 19.31 | 1.03 | 17.64 | + .64 | 3,112 | 142 | 142 | 2,828 | ..... | ..... |
| | Average, work ..... | | | | 21.18 | 1.17 | 17.83 | +2.18 | 3,845 | 162 | 140 | 3,530 | 33,675 | 79 |

*a* The form of apparatus used to measure the work was such that in all probability the work actually measured was but a small part of the extra work done.

The first rest period in each experiment was designed to test whether the subject was in nitrogen equilibrium. If so then the diet needed no change for the second rest period. If, however, the subject gained nitrogen the amount of protein supplied was diminished, while if there were a loss of nitrogen the protein was increased. Under the experimental conditions the effect of external muscular work on the excretion of nitrogen should be apparent when the results of the second and third periods are compared, due allowance being made for the nitrogen lag. In these two periods the basal diet remained the same, sufficient extra material, chiefly fat and carbohydrates, being added in the third period to supply the energy calculated to be sufficient for the muscular work performed, provided it is performed at the expense of nonnitrogenous nutrients, as is claimed by some physiologists.

On an average the diet in the second period contained 17.31 grams nitrogen, and that in the third period 21.18 grams, while 17.64 grams and 17.83 grams, respectively, was excreted in the urine in the two periods. The average amount excreted in the feces was practically the same in both cases. In other words, there was no increase in the amount of nitrogen in the urine which could be attributed to the external muscular work performed. It should be remembered that the muscular work was not very severe. The extra nitrogen in the diet is more than sufficient to account for the small excess observed in the third period. The results are referred to again in another place in connection with those obtained in 1899.

## EXPERIMENTS CARRIED ON IN 1898–99.

The work of the previous year was especially useful in showing how the method of investigation could be improved, and in indicating what phases of the subject needed more attention. It was evident, for one thing, that the nitrogen content of the food should be kept practically constant during the last two periods, and that the work period should be of longer duration and the exercise more active. With the exception of changes in these directions, the experiments of 1898–99 were carried on after the method already described.

The following schedule shows the relation of the different experiments and different periods of each experiment to each other, and indicates the duration of the different periods and intervals between the periods:

TABLE 29.—*General scheme of experiments and periods in experiments Nos. 9–16.*

| Number of experiment. | Subject. | Preliminary period, diet selected. | First rest period, diet tested. | | Interval, same diet as in first rest period. | Second rest period, diet adjusted. | | Interval, same diet as in second rest period. | Work period, diet increased. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Number of digestion experiment. | Duration. | | Number of digestion experiment. | Duration. | | Number of digestion experiment. | Duration. |
| | | | | *Days.* | *Days.* | | *Days.* | *Days.* | | *Days.* |
| 9 | C | Duration variable. | 99 | 2 | 1 | 100 | 3 | 0 | 101 | 6 |
| 10 | D | | 102 | 2 | 1 | 103 | 3 | 0 | 104 | 6 |
| 11 | E | | 105 | 2 | 1 | 106 | 3 | 0 | 107 | 6 |
| 12 | C | | 108 | 2 | 1 | 109 | 3 | 2 | 110 | 6 |
| 13 | D | | 111 | 2 | 1 | 112 | 3 | 2 | 113 | 6 |
| 14 | E | | 114 | 2 | 1 | 115 | 3 | 0 | 116 | 6 |
| 15 | C | | 117 | 2 | 1 | 118 | 3 | 0 | 119 | 6 |
| 16 | D | | 120 | 2 | 1 | 121 | 3 | 0 | 122 | 6 |

## EXPERIMENT NO. 9.

The results of experiment No. 9 are shown in Table 30. The experiment began with breakfast November 1, 1898, after a preliminary period, during which the proportions of the different food materials were selected according to the wishes of the subject, who was a chemist, 29 years of age, the same as in metabolism experiments Nos.

3, 6, and 8 of the previous year. His weight at the beginning of the experiment was 67.7 kilograms and at the end 66.6 kilograms. The first rest period (digestion experiment No. 99) continued for two days and was followed by an interval of one day, during which the nitrogen balance was determined approximately, and it was found that the subject was losing nitrogen, the amount as roughly computed being 1.07 grams per day. Later and more careful analyses showed the amount to be 1.05 grams. In order that the subject might approach as nearly as possible to nitrogen equilibrium, the amount of oatmeal in the daily ration was increased 37 grams. The separation of the feces was satisfactory—in fact, this was the case in all the experiments here recorded. The second rest period (digestion experiment No. 100) began with breakfast November 4 and continued three days, during which time the subject lost 0.4 kilogram in weight and also 9.36 grams of nitrogen or 3.12 grams per day, an amount nearly three times as large as that on the first rest period, although nearly a gram of nitrogen had been added to the daily diet in the increased amount of oatmeal.

The third or work period (digestion experiment No. 101) began with breakfast November 7, and continued six days. A sufficient amount of all kinds of food materials except milk had been prepared to suffice for the whole experiment, therefore no interval was necessary between the second rest period and the third or work period. The diet in this latter period was increased by 660 calories of energy per day through the addition of 50 grams of sugar, 53 grams of butter, 42 grams of bread, and the removal of 96 grams of milk in order to allow for the nitrogen supplied in the bread added. During the six days of this period the body weight remained the same, while there was a total gain of 7.23 grams of nitrogen, or an average of 1.2 grams per day.

Part of the work during this period consisted in walking up and down hill and part in turning the friction machine. The work was thus divided between muscles of the arms and legs. During the six days 20½ hours was expended in walking up and down hill. The amount of work performed in walking uphill was 2,238,600 foot-pounds, the heat equivalent of which is 722 calories. As previously explained, this covers only the product of the weight of the body, the height of the hill, and the number of times the trip was made. Owing to a lack of satisfactory methods of experimenting and calculating, no estimate can be given of the energy expended in forward progression when walking uphill or expended in walking downhill. The subject worked 1½ hours with the friction machine, during which time 126,000 foot-pounds of work, equivalent to 41 calories, was measured. The total measured work during the six days was therefore 2,364,600 foot-pounds, or 326,152 kilogrammeters, equivalent to 763 calories, or 127 calories per day. If the unmeasured work could be taken into account, these values would undoubtedly be considerably increased.

*Details of experiment No. 9.*

*Subject.*—Chemist A, 29 years of age.

*Weight (without clothing).*—At beginning of experiment, 67.7 kilograms (149.3 pounds); at end of first period, 66.8 kilograms; at beginning of second period, 67.05 kilograms; at end of second period, 66.59 kilograms; at beginning of third period, 66.59 kilograms; at end of third period and experiment, 66.49 kilograms (146.8 pounds).

The experiment commenced with breakfast November 1, 1898, and the first period continued two days. The second period commenced with breakfast November 4 and continued three days. The third period commenced with breakfast November 7 and continued six days.

TABLE 30.—*Results of experiment No. 9.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. TRIAL DIET. REST. (*Digestion experiment No. 99.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 401 | Milk | 4,000 | 605 | 28.40 | 178 | 231 | 196 | 32 | 3,920 |
| 402 | Oatmeal | 120 | 109 | 2.78 | 18 | 9 | 82 | 2 | 525 |
| 403 | Potato chips | 20 | 18 | .24 | 1 | 7 | 10 | 1 | 112 |
| 404 | Bread | 300 | 201 | 4.20 | 26 | 3 | 172 | 3 | 836 |
| 405 | Beef, canned | 100 | 43 | 3.64 | 23 | 20 | ..... | 4 | 304 |
| 406 | Butter | 10 | 9 | .01 | ..... | 9 | ..... | ..... | 92 |
| ..... | Coffee | 800 | 2 | .32 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 110 | 110 | ..... | ..... | ..... | 110 | ..... | 436 |
| | Total | ..... | 1,097 | 39.59 | 248 | 279 | 570 | 42 | 6,225 |
| 410 | Feces | 68 | 48 | 2.92 | 18 | 12 | 18 | 20 | 329 |
| 413 | Urine | 3,204 | ..... | 38.77 | ..... | ..... | ..... | ..... | 287 |
| ..... | Amount digested | ..... | 1,049 | 36.67 | 230 | 267 | 552 | 22 | 5,609 |
| | Coefficients of digestibility (per cent) | ..... | 95.6 | 92.7 | 92.7 | 95.7 | 96.8 | 52.4 | 90.0 |
| | SECOND PERIOD. DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. (*Digestion experiment No. 100.*) | | | | | | | | |
| 414 | Milk | 6,000 | 930 | 42.60 | 266 | 369 | 295 | 49 | 5,754 |
| 402 | Oatmeal | 291 | 264 | 6.75 | 42 | 23 | 199 | 6 | 1,273 |
| 403 | Potato chips | 30 | 27 | .35 | 2 | 10 | 15 | 1 | 168 |
| 404 | Bread | 450 | 302 | 6.30 | 40 | 5 | 257 | 4 | 1,254 |
| 405 | Canned beef | 150 | 64 | 5.46 | 34 | 30 | ..... | 6 | 456 |
| 406 | Butter | 15 | 13 | .02 | ..... | 13 | ..... | ..... | 138 |
| ..... | Coffee | 1,200 | 3 | .48 | 3 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 165 | 165 | ..... | ..... | ..... | 165 | ..... | 653 |
| | Total | ..... | 1,768 | 61.96 | 387 | 450 | 931 | 66 | 9,696 |
| 415 | Feces | 114 | 83 | 4.92 | 31 | 17 | 35 | 31 | 551 |
| 418 | Urine | 4,718 | ..... | 66.40 | ..... | ..... | ..... | ..... | 445 |
| | Amount digested | ..... | 1,685 | 57.04 | 356 | 433 | 896 | 35 | 8,700 |
| | Coefficients of digestibility (per cent) | ..... | 95.3 | 92.0 | 92.0 | 96.2 | 96.2 | 53.0 | 89.7 |

TABLE 30.—*Results of experiment No. 9*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | THIRD PERIOD. DIET INCREASED IN ENERGY. WORK. (*Digestion experiment No. 101.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 419 | Milk | 11,424 | 1,780 | 81.11 | 507 | 722 | 551 | 93 | 11,572 |
| 402 | Oatmeal | 582 | 527 | 13.50 | 84 | 45 | 398 | 11 | 2,547 |
| 403 | Potato chips | 60 | 55 | .71 | 4 | 21 | 30 | 2 | 36 |
| 404 | Bread | 1,152 | 772 | 16.13 | 101 | 13 | 658 | 10 | 3,209 |
| 405 | Canned beef | 300 | 128 | 10.92 | 68 | 60 | ..... | 11 | 912 |
| 406 | Butter | 228 | 202 | .30 | 2 | 200 | ..... | 7 | 2,106 |
| ..... | Coffee | 2,400 | 6 | .96 | 6 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 630 | 630 | ..... | ..... | ..... | 630 | ..... | 2,495 |
| | Total | ..... | 4,100 | 123.63 | 772 | 1,061 | 2,267 | 134 | 23,163 |
| 420 | Feces | 215 | 158 | 9.33 | 58 | 53 | 47 | 57 | 1,081 |
| 423 | Urine | 6,224 | ..... | 107.07 | ..... | ..... | ..... | ..... | 892 |
| | Amount digested | ..... | 3,942 | 114.30 | 714 | 1,008 | 2,220 | 77 | 21,190 |
| | Coefficients of digestibility (per cent) | ..... | 96.2 | 92.5 | 92.5 | 95.0 | 97.9 | 57.5 | 91.5 |

During the two days of the first rest period 3.204 grams of urine was eliminated containing 1.21 per cent or 38.77 grams nitrogen. The urine was not collected in several portions, but was combined for the two days.

The urine was collected in six-hour portions during the second rest period and the nitrogen determined as usual. The results are as follows:

TABLE 31.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 77).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 308 | 486 | 662 | 320 | 1,776 |
| Weight of nitrogen .....do.... | 4.50 | 6.22 | 9.93 | 4.16 | 24.81 |
| Per cent of nitrogen..... | 1.46 | 1.28 | 1.50 | 1.30 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 280 | 485 | 341 | 320 | 1,426 |
| Weight of nitrogen .....do.... | 4.65 | 6.94 | 5.35 | 4.48 | 21.42 |
| Per cent of nitrogen..... | 1.66 | 1.43 | 1.57 | 1.40 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 295 | 473 | 508 | 260 | 1,516 |
| Weight of nitrogen .....do.... | 4.48 | 5.58 | 6.81 | 3.30 | 20.17 |
| Per cent of nitrogen..... | 1.52 | 1.18 | 1.34 | 1.27 | ..... |

In the following table are shown the total weight of urine and the proportion of nitrogen for each six-hour interval during the six days of the third or work period and for one day following:

TABLE 32.—*Amount of nitrogen eliminated in urine (digestion experiment No. 78).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 299 | 344 | 498 | 248 | 1,389 |
| Weight of nitrogen .....do.... | 4.37 | 5.02 | 5.18 | 3.89 | 18.46 |
| Per cent of nitrogen..... | 1.46 | 1.46 | 1.04 | 1.57 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 292 | 377 | 321 | 210 | 1,200 |
| Weight of nitrogen .....do.... | 3.83 | 4.79 | 4.82 | 3.49 | 16.93 |
| [1] Per cent of nitrogen..... ..... | 1.31 | 1.27 | 1.50 | 1.66 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 250 | 235 | 179 | 190 | 854 |
| Weight of nitrogen .....do.... | 3.93 | 4.35 | 4.15 | 3.74 | 16.17 |
| Per cent of nitrogen..... | 1.57 | 1.85 | 2.32 | 1.97 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 201 | 247 | 223 | 171 | 842 |
| Weight of nitrogen .....do.... | 3.72 | 4.94 | 5.22 | 3.54 | 17.42 |
| Per cent of nitrogen..... | 1.85 | 2.00 | 2.34 | 2.07 | ..... |
| Fifth day: | | | | | |
| Weight of urine.....grams.. | 228 | 290 | 225 | 211 | 954 |
| Weight of nitrogen .....do.... | 4.42 | 5.42 | 5.20 | 4.18 | 19.22 |
| Per cent of nitrogen..... | 1.94 | 1.87 | 2.31 | 1.98 | ..... |
| Sixth day: | | | | | |
| Weight of urine.....grams.. | 248 | 292 | 212 | 233 | 985 |
| Weight of nitrogen .....do.... | 4.66 | 5.37 | 4.60 | 4.24 | 18.87 |
| Per cent of nitrogen..... | 1.88 | 1.84 | 2.17 | 1.82 | ..... |
| Seventh day (first day after close of period): | | | | | |
| Weight of urine.....grams.. | 425 | 478 | 836 | 348 | 2,087 |
| Weight of nitrogen .....do.... | 5.91 | 6.07 | 9.03 | 4.38 | 25.39 |
| Per cent of nitrogen..... | 1.39 | 1.27 | 1.08 | 1.26 | ..... |

Following the same methods as in the series of experiments conducted in 1898, the average daily balance of income and outgo of nitrogen was calculated from the data and are recorded above. The results are given in Table 33. The effect of muscular work on the excretion of nitrogen is discussed when the series is considered as a whole:

TABLE 33.—*Daily income and outgo of nitrogen in experiment No. 9.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet..... | 2 | 19.80 | 1.46 | 19.39 | −1.05 |
| Second period, rest, adjusted diet..... | 3 | 20.65 | 1.64 | 22.13 | −3.12 |
| Third period, work, diet increased 629 calories..... | 6 | 20.61 | 1.55 | 17.85 | +1.21 |

## EXPERIMENT NO. 10.

This experiment was carried on coincident with experiment No. 9 with a chemist 22 years of age, weighing 52.96 kilograms at the beginning of the experiment and 52.27 kilograms at its close. The first rest period (digestion experiment No. 102) continued two days and was followed by an interval of one day, during which the nitrogen balance was determined approximately. It was found that there

was an average daily gain of 3.2 grams of nitrogen. The daily ration was therefore reduced by 480 grams of milk. The second rest period (digestion experiment No. 103) began with breakfast November 4 and continued three days, during which time the subject lost 0.22 kilogram in body weight and 3.8 grams of nitrogen. The work period (digestion experiment No. 104) began with breakfast November 7 and continued six days. The ration was increased about 550 calories per day by the addition of 30 grams of sugar, 35 of butter, 58 of bread, and 20 of potatoes, the milk being correspondingly reduced 163 grams. During the six days of this period the subject lost 0.34 kilogram in body weight and stored 2.45 grams of nitrogen, or 0.41 gram per day. He was thus not far from a condition of nitrogen equilibrium. The difference between the average amount of protein metabolized per day in this and the second rest period was 1.69 grams.

The work consisted, as in the preceding experiment, in walking up and down hill and turning the friction machine. In addition the subject worked by walking up and down stairs one hour. The total time expended in walking up and down hill was twenty-one and one-half hours, during which time the calculated work amounted to 2,198,625 foot-pounds with a heat equivalent of 709 calories. In walking up and down stairs the work (calculated in the same way as that performed in walking up and down hill) amounted to 122,760 foot-pounds with a heat equivalent of 40 calories. The measured work in the one and one-half hours spent upon the friction machine amounted to 129,339 foot-pounds, equivalent to 42 calories of energy. The total measured work performed during six days was thus 2,450,724 foot-pounds, or 337,872 kilogrammeters, the heat equivalent of which is 791 calories, or an average of 132 per day. The actual amount must have been considerably more.

The result of the experiments follow:

*Details of experiment No. 10.*

*Subject.*—Chemist B, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 52.96 kilograms (116.8 pounds); at end of first period, 52.27 kilograms; at beginning of second period, 52.72 kilograms; at end of second period, 52.50 kilograms; at beginning of third period, 52.61 kilograms; at end of third period and experiment, 52.27 kilograms (115.3 pounds).

The experiment commenced with breakfast November 1, 1898, and the first period continued two days. The second period commenced with breakfast November 4 and continued three days. The third period commenced with breakfast November 7 and continued six days.

TABLE 34.—*Results of experiment No. 10.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N× 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 102.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 401 | Milk | 2,700 | 408 | 19.17 | 120 | 156 | 132 | 22 | 2,646 |
| 402 | Oatmeal | 140 | 127 | 3.25 | 20 | 11 | 96 | 3 | 613 |
| 403 | Potato chips | 40 | 37 | .47 | 3 | 14 | 20 | 1 | 224 |
| 404 | Bread | 200 | 134 | 2.80 | 18 | 2 | 114 | 2 | 557 |
| 405 | Canned beef | 100 | 43 | 3.64 | 23 | 20 | ..... | 4 | 304 |
| 406 | Butter | 10 | 9 | .01 | ..... | 9 | ..... | ..... | 92 |
| ..... | Coffee | 250 | 1 | .10 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 200 | 200 | ..... | ..... | ..... | 200 | ..... | 792 |
| | Total | ..... | 959 | 29.44 | 185 | 212 | 562 | 32 | 5,228 |
| 411 | Feces | 65 | 51 | 2.62 | 16 | 25 | 10 | 14 | 376 |
| 413a | Urine | 2,245 | ..... | 20.43 | ..... | ..... | ..... | ..... | 211 |
| | Amount digested | ..... | 908 | 26.82 | 169 | 187 | 552 | 18 | 4,641 |
| | Coefficients of digestibility (per cent) | ..... | 94.7 | 91.4 | 91.4 | 88.2 | 98.2 | 56.3 | 88.8 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 103.*) | | | | | | | | |
| 414 | Milk | 2,610 | 404 | 18.53 | 116 | 160 | 128 | 21 | 2,503 |
| 402 | Oatmeal | 210 | 190 | 4.87 | 30 | 16 | 144 | 4 | 919 |
| 403 | Potato chips | 60 | 55 | .71 | 4 | 21 | 30 | 2 | 336 |
| 404 | Bread | 300 | 201 | 4.20 | 26 | 3 | 172 | 3 | 836 |
| 405 | Canned beef | 150 | 64 | 5.46 | 34 | 30 | ..... | 6 | 456 |
| 406 | Butter | 15 | 13 | .02 | ..... | 13 | ..... | ..... | 139 |
| ..... | Coffee | 375 | 1 | .15 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 300 | 300 | ..... | ..... | ..... | 300 | ..... | 1,188 |
| | Total | ..... | 1,228 | 33.94 | 211 | 243 | 774 | 36 | 6,377 |
| 416 | Feces | 72 | 57 | 3.54 | 22 | 22 | 13 | 15 | 389 |
| 418a | Urine | 2,304 | ..... | 34.20 | ..... | ..... | ..... | ..... | 236 |
| | Amount digested | ..... | 1,171 | 30.40 | 189 | 221 | 761 | 21 | 5,752 |
| | Coefficients of digestibility (per cent) | ..... | 95.4 | 89.6 | 89.6 | 91.0 | 98.3 | 58.3 | 90.2 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 104.*) | | | | | | | | |
| 419 | Milk | 4,242 | 661 | 30.12 | 188 | 268 | 205 | 34 | 4,297 |
| 402 | Oatmeal | 420 | 380 | 9.74 | 61 | 32 | 287 | 8 | 1,838 |
| 403 | Potato chips | 240 | 221 | 2.83 | 18 | 82 | 121 | 9 | 1,345 |
| 404 | Bread | 948 | 635 | 13.27 | 83 | 10 | 542 | 8 | 2,641 |
| 405 | Canned beef | 300 | 128 | 10.92 | 68 | 60 | ..... | 11 | 912 |
| 406 | Butter | 240 | 213 | .31 | 2 | 211 | ..... | 7 | 2,216 |
| ..... | Coffee | 750 | 2 | .30 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 780 | 780 | ..... | ..... | ..... | 780 | ..... | 3,089 |
| | Total | ..... | 3,020 | 67.49 | 422 | 663 | 1,935 | 77 | 16,338 |
| 421 | Feces | 137 | 109 | 6.80 | 43 | 46 | 20 | 28 | 743 |
| 423a | Urine | 3,933 | ..... | 58.24 | ..... | ..... | ..... | ..... | 474 |
| | Amount digested | ..... | 2,911 | 60.69 | 379 | 617 | 1,915 | 49 | 15,121 |
| | Coefficients of digestibility (per cent) | ..... | 96.4 | 89.8 | 89.8 | 93.1 | 99.0 | 63.6 | 92.5 |

In the first rest period the urine was collected in one portion. The total elimination was 2,245 grams, containing 0.91 per cent or 20.43 grams nitrogen.

The urine was collected in portions corresponding to six-hour intervals during the second rest period. The statistical data are as follows:

TABLE 35.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 80).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 584 | 219 | 160 | 112 | 1,075 |
| Weight of nitrogen .....do.... | 6.72 | 2.93 | 2.78 | 2.03 | 14.46 |
| Per cent of nitrogen..... | 1.15 | 1.34 | 1.74 | 1.81 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 147 | 171 | 127 | 107 | 552 |
| Weight of nitrogen .....do.... | 2.13 | 2.68 | 2.54 | 2.05 | 9.40 |
| Per cent of nitrogen..... | 1.45 | 1.57 | 2.00 | 1.92 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 180 | 187 | 126 | 184 | 677 |
| Weight of nitrogen .....do.... | 2.50 | 2.86 | 2.31 | 2.67 | 10.34 |
| Per cent of nitrogen..... | 1.39 | 1.53 | 1.83 | 1.45 | ..... |

The urine was collected in six-hour portions during the six days of the third work period and the day following, and the nitrogen determined by the usual method. The results are as follows:

TABLE 36.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 81).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 228 | 239 | 195 | 140 | 802 |
| Weight of nitrogen .....do.... | 2.55 | 2.63 | 2.9[illegible] | 2.18 | 10.29 |
| Per cent of nitrogen..... | 1.12 | 1.10 | 1.50 | 1.56 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 227 | 186 | 130 | 109 | 652 |
| Weight of nitrogen .....do.... | 2.59 | 2.46 | 2.60 | 2.01 | 9.66 |
| Per cent of nitrogen..... | 1.14 | 1.32 | 2.00 | 1.84 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 225 | 171 | 106 | 105 | 607 |
| Weight of nitrogen .....do.... | 2.70 | 2.36 | 1.99 | 2.10 | 9.15 |
| Per cent of nitrogen..... | 1.20 | 1.38 | 1.88 | 2.00 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 158 | 193 | 122 | 103 | 576 |
| Weight of nitrogen .....do.... | 2.40 | 2.62 | 2.35 | 2.02 | 9.39 |
| Per cent of nitrogen..... | 1.52 | 1.36 | 1.93 | 1.96 | ..... |
| Fifth day: | | | | | |
| Weight of urine..... ....grams.. | 205 | 212 | 137 | 104 | 658 |
| Weight of nitrogen .....do.... | 2.75 | 2.90 | 2.47 | 2.02 | 10.14 |
| Per cent of nitrogen..... | 1.34 | 1.37 | 1.80 | 1.94 | ..... |
| Sixth day: | | | | | |
| Weight of urine.....grams.. | 197 | 199 | 144 | 98 | 638 |
| Weight of nitrogen .....do.... | 2.58 | 2.37 | 2.76 | 1.90 | 9.61 |
| Per cent of nitrogen..... | 1.31 | 1.19 | 1.92 | 1.94 | ..... |
| Seventh day: | | | | | |
| Weight of urine.....grams.. | 332 | 488 | 122 | 140 | 1,082 |
| Weight of nitrogen .....do.... | 3.69 | 5.22 | 1.88 | 1.95 | 12.74 |
| Per cent of nitrogen..... | 1.11 | 1.07 | 1.54 | 1.39 | ..... |

As in the preceding experiment, the average daily balance of income and outgo of nitrogen was calculated. The results follow.

TABLE 37.—*Daily income and outgo of nitrogen in experiment No. 10.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 14.72 | 1.31 | 10.21 | +3.20 |
| Second period, rest, adjusted diet | 3 | 11.31 | 1.18 | 11.40 | −1.27 |
| Third period, work, diet increased 597 calories | 6 | 11.25 | 1.13 | 9.71 | + .41 |

## EXPERIMENT NO. 11.

This experiment began with breakfast November 1, 1898, and continued twelve days. The subject was a student 30 years of age. His weight at the beginning of the experiment was 57.36 kilograms and at the close 55.91 kilograms. The first rest period (digestion experiment No. 105) covered two days, November 2 and 3, and was followed by an interval of one day. The nitrogen balance was then calculated approximately. It was found that there was a large gain of nitrogen. Therefore the milk in the daily ration was decreased 734 grams and the second rest period (digestion experiment No. 106) was begun. During the three days of this period the subject lost an average of 1.4 grams of nitrogen per day and a total of 0.41 kilogram in body weight. The work period (digestion experiment No. 107) began with breakfast November 7, and continued six days, during which the subject walked up and down hill, and, in addition, worked a little with the friction machine.

The daily diet in the work period was increased by the addition of 50 grams of sugar, 33 grams of butter, and 42 grams of bread. These materials increased the nitrogen in the food by about 0.6 gram, and this increase was accordingly offset by a reduction of 96 grams per day in the milk. The increase was planned and carried out before the analyses had been completed. It was the aim to add about 500 calories per day to the diet, but the final calculations showed considerable larger increase. The subject was now quite nearly in nitrogen equilibrium, there being a gain of about one-third gram of nitrogen per day. During the six days of this work period he worked twenty-seven hours walking up and down hill, and, as calculated in lifting himself uphill, performed 2,642,688 foot-pounds of work, the heat equivalent of which is 852 calories. In addition, he worked one hour with the machine, which recorded 95,697 foot-pounds, or 31 calories of energy. The total measured work was therefore 2,738,385 foot-pounds, or 377,711 kilogrammeters, the heat equivalent of which is 883 calories, or 147 calories per day. The work actually performed must have been considerably more. During the six days of this

period the body weight of the subject remained very nearly constant, the total apparent loss (0.27 kilogram) being too small to take into account, as it is within the limits of experimental error.

Table 38 gives the results of the experiment in detail.

*Details of experiment No. 11.*

*Subject.*—Student, 30 years of age.

*Weight (without clothing).*—At beginning of experiment, 57.36 kilograms (126.5 pounds); at end of first period, 56.32 kilograms; at beginning of second period, 56.86 kilograms; at end of second period, 56.45 kilograms; at beginning of third period, 56.18 kilograms; at end of third period and experiment, 55.91 kilograms (123.2 pounds).

The experiment commenced with breakfast November 1, 1898, and the first period continued two days. The second period commenced with breakfast November 4 and continued three days. The third period commenced with breakfast November 7 and continued six days.

TABLE 38.—*Results of experiment No. 11.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 105.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 401 | Milk | 3,000 | 454 | 21.30 | 133 | 174 | 147 | 24 | 2,940 |
| 402 | Oatmeal | 120 | 109 | 2.78 | 18 | 9 | 82 | 2 | 525 |
| 403 | Potato chips | 30 | 27 | .35 | 2 | 10 | 15 | 1 | 168 |
| 404 | Bread | 120 | 80 | 1.68 | 10 | 1 | 69 | 1 | 334 |
| 405 | Canned beef | 200 | 86 | 7.28 | 46 | 40 | ..... | 7 | 608 |
| 406 | Butter | 10 | 9 | .01 | ..... | 9 | ..... | ..... | 92 |
| ..... | Coffee | 350 | 1 | .14 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 250 | 250 | ..... | ..... | ..... | 250 | ..... | 990 |
| | Total | ..... | 1,016 | 33.54 | 210 | 243 | 563 | 35 | 5,657 |
| 412 | Feces | 61 | 48 | 2.26 | 15 | 11 | 22 | 13 | 355 |
| 413b | Urine | 2,410 | ..... | 20.97 | ..... | ..... | ..... | ..... | 244 |
| | Amount digested | ..... | 968 | 31.28 | 195 | 232 | 541 | 22 | 5,058 |
| | Coefficients of digestibility (per cent) | ..... | 95.3 | 92.9 | 92.9 | 95.5 | 96.1 | 62.9 | 89.4 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 106.*) | | | | | | | | |
| 414 | Milk | 2,298 | 356 | 16.32 | 102 | 141 | 113 | 19 | 2,204 |
| 402 | Oatmeal | 180 | 163 | 4.18 | 26 | 14 | 123 | 3 | 788 |
| 403 | Potato chips | 45 | 41 | .53 | 3 | 15 | 23 | 2 | 252 |
| 404 | Bread | 180 | 121 | 2.52 | 16 | 2 | 103 | 2 | 501 |
| 405 | Canned beef | 300 | 128 | 10.92 | 68 | 60 | ..... | 11 | 912 |
| 406 | Butter | 15 | 13 | .02 | ..... | 13 | ..... | ..... | 139 |
| ..... | Coffee | 525 | 1 | .21 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 375 | 375 | ..... | ..... | ..... | 375 | ..... | 1,485 |
| | Total | ..... | 1,198 | 34.70 | 216 | 245 | 737 | 37 | 6,281 |
| 417 | Feces | 65 | 51 | 2.73 | 17 | 12 | 22 | 14 | 365 |
| 418b | Urine | 2,788 | ..... | 35.10 | ..... | ..... | ..... | ..... | 249 |
| | Amount digested | ..... | 1,147 | 31.97 | 199 | 233 | 715 | 23 | 5,667 |
| | Coefficients of digestibility (per cent) | ..... | 95.8 | 92.1 | 92.1 | 95.1 | 97.0 | 62.2 | 90.2 |

TABLE 38.—*Results of experiment No. 11*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | THIRD PERIOD. DIET INCREASED IN ENERGY. WORK. (*Digestion experiment No. 107.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 419 | Milk | 4,020 | 626 | 28.54 | 178 | 254 | 194 | 33 | 4,072 |
| 402 | Oatmeal | 360 | 326 | 8.35 | 52 | 28 | 246 | 7 | 1,576 |
| 403 | Potato chips | 90 | 83 | 1.06 | 7 | 31 | 45 | 3 | 504 |
| 404 | Bread | 612 | 410 | 8.57 | 53 | 7 | 350 | 5 | 1,705 |
| 405 | Canned beef | 600 | 257 | 21.84 | 136 | 121 | ..... | 22 | 1,824 |
| 406 | Butter | 228 | 202 | .30 | 2 | 200 | ..... | 7 | 2,106 |
| ..... | Coffee | 1,050 | 3 | .42 | 3 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 1,050 | 1,050 | ..... | ..... | ..... | 1,050 | ..... | 4,158 |
| | Total | ..... | 2,957 | 69.08 | 431 | 641 | 1,885 | 77 | 15,945 |
| 422 | Feces | 125 | 101 | 5.53 | 34 | 32 | 35 | 24 | 727 |
| 423b | Urine | 4,666 | ..... | 65.56 | ..... | ..... | ..... | ..... | 496 |
| | Amount digested | ..... | 2,856 | 63.55 | 397 | 609 | 1,850 | 53 | 14,722 |
| | Coefficients of digestibility (per cent) | ..... | 96.6 | 92.1 | 92.1 | 95.0 | 98.1 | 68.8 | 92.3 |

The urine for the two days of the first rest period amounted to 2,410 grams, containing 0.87 per cent or 20.97 grams nitrogen. It was collected in one portion.

The urine was collected in six-hour portions in the second rest period, and the nitrogen determined by the usual method. Following are the statistical details:

TABLE 39.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 83).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 470 | | 264 | 330 | 1,064 |
| Weight of nitrogen .....do.... | 6.11 | | 3.59 | 3.83 | 13.53 |
| Per cent of nitrogen..... | 1.30 | | 1.36 | 1.16 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 181 | 178 | 223 | 194 | 776 |
| Weight of nitrogen .....do.... | 2.55 | 2.78 | 3.23 | 2.64 | 11.20 |
| Per cent of nitrogen..... | 1.41 | 1.56 | 1.45 | 1.36 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 208 | 360 | 230 | 150 | 948 |
| Weight of nitrogen .....do.... | 2.54 | 3.49 | 2.28 | 2.06 | 10.37 |
| Per cent of nitrogen..... | 1.22 | .97 | .99 | 1.37 | ..... |

As usual the urine was collected in six-hour portions in the third or work period and the amount of nitrogen determined with the following results:

TABLE 40.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 84).*

| | 8 a.m. to 2 p.m. | 2 p.m. to 8 p.m. | 8 p.m. to 2 a.m. | 2 a.m. to 8 a.m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 113 | 270 | 286 | 223 | 892 |
| Weight of nitrogen .....do.... | 1.72 | 3.46 | 3.95 | 3.66 | 12.79 |
| Per cent of nitrogen..... | 1.52 | 1.28 | 1.38 | 1.64 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 176 | 204 | 210 | 231 | 821 |
| Weight of nitrogen .....do.... | 2.89 | 2.53 | 3.44 | 3.16 | 12.02 |
| Per cent of nitrogen..... | 1.64 | 1.24 | 1.64 | 1.37 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 145 | 188 | 143 | 150 | 626 |
| Weight of nitrogen .....do.... | 2.16 | 2.78 | 2.55 | 2.64 | 10.13 |
| Per cent of nitrogen..... | 1.49 | 1.48 | 1.78 | 1.76 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 161 | 205 | 205 | 145 | 716 |
| Weight of nitrogen .....do.... | 2.59 | 2.62 | 2.64 | 2.39 | 10.24 |
| Per cent of nitrogen..... | 1.61 | 1.28 | 1.29 | 1.65 | ..... |
| Fifth day: | | | | | |
| Weight of urine.....grams.. | 207 | 249 | 226 | 144 | 826 |
| Weight of nitrogen .....do.... | 2.36 | 3.11 | 2.73 | 2.29 | 10.49 |
| Per cent of nitrogen..... | 1.14 | 1.25 | 1.21 | 1.59 | ..... |
| Sixth day: | | | | | |
| Weight of urine.....grams.. | 203 | 258 | 199 | 125 | 785 |
| Weight of nitrogen .....do.... | 2.21 | 2.76 | 2.73 | 2.19 | 9.89 |
| Per cent of nitrogen..... | 1.09 | 1.07 | 1.37 | 1.75 | ..... |
| Seventh day: | | | | | |
| Weight of urine.....grams.. | 240 | 336 | 160 | 220 | 956 |
| Weight of nitrogen .....do.... | 3.24 | 3.83 | 2.26 | 2.62 | 11.95 |
| Per cent of nitrogen..... | 1.35 | 1.14 | 1.41 | 1.19 | ..... |

The exeretion of nitrogen varied somewhat in the three periods. Table 41 shows the average daily balance of income and outgo of the element:

TABLE 41.—*Daily income and outgo of nitrogen in experiment No. 11.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet..... | 2 | 16.77 | 1.13 | 10.48 | +5.16 |
| Second period, rest, adjusted diet..... | 3 | 11.57 | .91 | 11.70 | −1.04 |
| Third period, work, diet increased 564 calories..... | 6 | 11.51 | .92 | 10.93 | − .34 |

## EXPERIMENT NO. 12.

Experiment No. 12 began with breakfast November 29, 1898, and continued fourteen days, of which eleven belonged to the experiment proper, and three to intervals between the periods. The results are summarized in Table 42. The subject was a chemist, the same as in experiment No. 9. At the beginning of the experiment his weight was 67.73 kilograms and at the close 66.32 kilograms. During the two days of the first rest period (digestion experiment No. 108) there was a slight loss of nitrogen. The diet in the second rest period (digestion experiment No. 109), which began with breakfast December 2, was

therefore increased slightly, 21 grams of oatmeal per day being added. In spite of this increase there was a loss of nitrogen amounting to 0.87 gram per day. The work period (digestion experiment No. 110) began with breakfast December 7 and continued six days. The diet was changed by increasing the quantity of sugar 50 grams, the butter 35 grams, and the bread 50 grams. The milk was reduced 116 grams in order to keep the nitrogen in the ration as nearly as possible the same as in the preceding period. The net increase in fuel value was 457 calories per day. The work done consisted in walking up and down hill, riding a stationary bicycle, and turning the friction machine. Sixteen hours were spent in walking up and down hill, during which time 81 trips were made. In lifting the body 1,726,920 foot-pounds of work was performed, the heat equivalent of which is 557 calories. The duration of the work upon the stationary bicycle was four hours, during which there were 9,477 revolutions of the pedals. The calculated work produced amounted to 530,712 foot-pounds. The heat equivalent of this is 171 calories. Four hours were expended upon the friction machine, 470,400 foot-pounds of work being recorded, the heat equivalent of which is 152 calories. The total measured muscular work during the six days amounted to 2,728,032 foot-pounds or 376,280 kilogrammeters, equivalent to 880 calories of energy or 147 calories per day. The total amount produced must have been much more. During the six days of this work period the subject maintained the same body weight and gained 1.83 grams of nitrogen. It is thus seen that although he was very nearly in nitrogen equilibrium he was gaining a trifle as contrasted with the small loss observed during the previous rest period with almost no muscular work, and a diet supplying the same amount of nitrogen, but a smaller amount of energy.

*Details of experiment No. 12.*

*Subject.*—Chemist A, 29 years of age.

*Weight (without clothing).*—At beginning of experiment, 67.73 kilograms (149.3 pounds); at end of first period, 66.32 kilograms; at beginning of second period, 66.32 kilograms; at end of second period, 66.32 kilograms; at beginning of third period, 66.32 kilograms; at end of third period and experiment, 66.32 kilograms (146.2 pounds).

The experiment commenced with breakfast November 29, 1898, and the first period continued two days. The second period commenced with breakfast December 2 and continued three days. The third period commenced with breakfast December 7 and continued six days.

TABLE 42.—*Results of experiment No. 12.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 108.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 425 | Milk | 4,000 | 636 | 28.80 | 180 | 266 | 190 | 32 | 4,092 |
| 426 | Oatmeal | 140 | 126 | 3.22 | 20 | 11 | 95 | 3 | 607 |
| 427 | Potato chips | 20 | 18 | .23 | 1 | 6 | 11 | 1 | 106 |
| 428 | Bread | 380 | 239 | 5.05 | 31 | 4 | 204 | 3 | 983 |
| 429 | Canned beef | 100 | 36 | 4.03 | 25 | 11 | ..... | 5 | 231 |
| 430 | Butter | 10 | 9 | .23 | ..... | 9 | ..... | ..... | 88 |
| 431 | Gelatin | 50 | 49 | .50 | 3 | ..... | 46 | ..... | 198 |
| ..... | Coffee | 800 | 2 | .32 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 100 | 100 | ..... | ..... | ..... | 100 | ..... | 396 |
| | Total | ..... | 1,215 | 42.38 | 262 | 307 | 646 | 44 | 6,701 |
| 433 | Feces | 71 | 52 | 3.04 | 19 | 17 | 16 | 19 | 357 |
| 435 | Urine | 4,149 | ..... | 41.49 | ..... | ..... | ..... | ..... | 304 |
| | Amount digested | ..... | 1,163 | 39.34 | 243 | 290 | 630 | 25 | 6,040 |
| | Coefficients of digestibility (per cent) | ..... | 95.7 | 92.8 | 92.8 | 94.5 | 97.5 | 56.8 | 90.1 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 109.*) | | | | | | | | |
| 436 | Milk | 6,000 | 948 | 45.00 | 281 | 389 | 278 | 47 | 6,270 |
| 426 | Oatmeal | 273 | 245 | 6.28 | 39 | 21 | 185 | 5 | 1,184 |
| 427 | Potato chips | 30 | 27 | .34 | 2 | 8 | 17 | 1 | 159 |
| 428 | Bread | 570 | 358 | 7.58 | 47 | 6 | 305 | 5 | 1,475 |
| 429 | Canned beef | 150 | 54 | 6.05 | 38 | 16 | ..... | 7 | 347 |
| 430 | Butter | 15 | 13 | .03 | ..... | 13 | ..... | ..... | 133 |
| 431 | Gelatin | 75 | 74 | .74 | 5 | ..... | 69 | ..... | 297 |
| ..... | Coffee | 1,200 | 3 | .48 | 3 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 150 | 150 | ..... | ..... | ..... | 150 | ..... | 594 |
| | Total | ..... | 1,872 | 66.50 | 415 | 453 | 1,004 | 65 | 10,459 |
| 437 | Feces | 116 | 86 | 4.92 | 31 | 20 | 35 | 30 | 556 |
| 439 | Urine | 5,140 | ..... | 64.18 | ..... | ..... | ..... | ..... | 480 |
| | Amount digested | ..... | 1,786 | 61.58 | 384 | 433 | 969 | 35 | 9,423 |
| | Coefficients of digestibility (per cent) | ..... | 95.4 | 92.5 | 92.5 | 95.6 | 96.5 | 53.9 | 90.1 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 110.*) | | | | | | | | |
| 440 | Milk | 11,304 | 1,815 | 83.65 | 523 | 763 | 529 | 90 | 11,462 |
| 426 | Oatmeal | 546 | 490 | 12.56 | 79 | 41 | 370 | 11 | 2,368 |
| 427 | Potato chips | 60 | 55 | .68 | 4 | 17 | 34 | 2 | 319 |
| 428 | Bread | 1,440 | 906 | 19.15 | 119 | 16 | 771 | 12 | 3,725 |
| 429 | Canned beef | 300 | 108 | 12.09 | 76 | 32 | ..... | 14 | 693 |
| 430 | Butter | 240 | 213 | .55 | 4 | 209 | ..... | 8 | 2,122 |
| 431 | Gelatin | 150 | 148 | 1.49 | 9 | 1 | 138 | ..... | 594 |
| ..... | Coffee | 2,400 | 6 | .96 | 6 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 600 | 600 | ..... | ..... | ..... | 600 | ..... | 2,376 |
| | Total | ..... | 4,341 | 131.13 | 820 | 1,079 | 2,442 | 137 | 23,659 |
| 441 | Feces | 227 | 170 | 9.74 | 61 | 48 | 61 | 57 | 1,112 |
| 443 | Urine | 7,251 | ..... | 119.56 | ..... | ..... | ..... | ..... | 949 |
| | Amount digested | ..... | 4,171 | 121.39 | 759 | 1,031 | 2,381 | 80 | 21,598 |
| | Coefficients of digestibility (per cent) | ..... | 96.1 | 92.6 | 92.6 | 95.6 | 97.5 | 58.4 | 91.3 |

The urine for the first rest period was collected in one portion which amounted to 4,149 grams, containing 1 per cent or 41.49 grams nitrogen.

The elimination of nitrogen in the urine was determined in portions collected during six-hour intervals in the second rest period. The results are shown in the following table:

TABLE 43.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 86).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 386 | 398 | 367 | 324 | 1,475 |
| Weight of nitrogen .....do.... | 5.44 | 6.49 | 6.02 | 4.41 | 22.36 |
| Per cent of nitrogen..... | 1.41 | 1.63 | 1.64 | 1.36 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 445 | 377 | 495 | 314 | 1,631 |
| Weight of nitrogen .....do.... | 5.25 | 5.35 | 6.09 | 4.24 | 20.93 |
| Per cent of nitrogen..... | 1.18 | 1.42 | 1.23 | 1.35 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 595 | 836 | 321 | 282 | 2,034 |
| Weight of nitrogen .....do.... | 5.41 | 6.44 | 5.04 | 4.00 | 20.89 |
| Per cent of nitrogen..... | .91 | .77 | 1.57 | 1.42 | ..... |

The urine was collected in six-hour portions during the third or work period and the nitrogen determined by the usual method. The results are as follows:

TABLE 44.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 87).*

| | 8 a. m. to 2 p. m. | 2 p. m. to 8 p. m. | 8 p. m. to 2 a. m. | 2 a. m. to 8 a. m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 275 | 279 | 268 | 249 | 1,071 |
| Weight of nitrogen .....do.... | 5.06 | 4.94 | 5.82 | 4.56 | 20.38 |
| Per cent of nitrogen..... | 1.84 | 1.77 | 2.17 | 1.83 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 332 | 232 | 240 | 262 | 1,066 |
| Weight of nitrogen .....do.... | 5.38 | 4.64 | 5.42 | 4.56 | 20.00 |
| Per cent of nitrogen..... | 1.62 | 2.00 | 2.26 | 1.74 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 307 | 399 | 262 | 253 | 1,221 |
| Weight of nitrogen .....do.... | 5.07 | 5.67 | 5.06 | 4.02 | 19.82 |
| Per cent of nitrogen..... | 1.65 | 1.42 | 1.93 | 1.59 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 329 | 422 | 234 | 292 | 1,277 |
| Weight of nitrogen .....do.... | 4.61 | 5.11 | 5.10 | 4.53 | 19.35 |
| Per cent of nitrogen..... | 1.40 | 1.21 | 2.18 | 1.55 | ..... |
| Fifth day: | | | | | |
| Weight of urine.....grams.. | 353 | 409 | 315 | 225 | 1,302 |
| Weight of nitrogen .....do.... | 4.59 | 5.97 | 5.67 | 3.85 | 20.08 |
| Per cent of nitrogen..... | 1.30 | 1.46 | 1.80 | 1.71 | ..... |
| Sixth day: | | | | | |
| Weight of urine.....grams.. | 315 | 439 | 285 | 275 | 1,314 |
| Weight of nitrogen .....do.... | 4.35 | 5.66 | 5.44 | 4.48 | 19.93 |
| Per cent of nitrogen..... | 1.38 | 1.29 | 1.91 | 1.63 | ..... |
| Seventh day: | | | | | |
| Weight of urine.....grams.. | 348 | 337 | 296 | 309 | 1,290 |
| Weight of nitrogen .....do.... | 5.05 | 6.44 | 5.71 | 4.85 | 22.05 |
| Per cent of nitrogen..... | 1.45 | 1.91 | 1.93 | 1.57 | ..... |

In Table 45 the average daily balance of income and outgo for nitrogen for the two periods of rest and the period of muscular work is shown.

TABLE 45.—*Daily income and outgo of nitrogen in experiment No. 12.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain(+), loss(−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 21.19 | 1.52 | 20.75 | −1.08 |
| Second period, rest, adjusted diet | 3 | 22.16 | 1.64 | 21.39 | − .87 |
| Third period, work, diet increased 457 calories | 6 | 21.86 | 1.62 | 19.93 | + .31 |

## EXPERIMENT NO. 13.

This experiment was carried on with the same subject as experiment No. 10. It began with breakfast November 29, 1898, and covered fourteen days, eleven of which were included in the three periods of the experiment, the other three covering the time between the periods. It was found that the subject was gaining about 4 grams of nitrogen a day during two days of the first rest period (digestion experiment No. 111). The daily diet was therefore reduced by 571 grams of milk, and the second rest period (digestion experiment No. 112) began with breakfast December 2, continuing three days. In this time there was a very slight loss of nitrogen, amounting to but 0.1 gram per day, and also a very slight loss in body weight. An intermediate period of two days followed the close of the second rest period. The third or work period (digestion experiment No. 113) began with breakfast December 7, and continued six days, during which the subject performed external muscular work by walking up and down hill, walking up and down stairs, riding a stationary bicycle, and turning the friction machine. The diet was the same as in the second rest period, except that the sugar was increased 30 grams, the butter 35 grams, the bread 58 grams, and the potatoes 20 grams, making an increase of 649 calories of energy and a little over a gram of nitrogen. In order to obtain practically the same amount of nitrogen in this diet as in the preceding, the daily quantity of milk was reduced 169 grams, equivalent to 171 calories, making the net increase in the diet 478 calories per day. During the six days, thirteen hours were expended in making 78 trips up and down hill. According to the method of calculation followed, this would produce 1,371,942 foot-pounds of work, equivalent to 442 calories. One hour was spent in walking up and down stairs. Following the method of calculation alluded to above, this would produce 98,208 foot-pounds, equivalent to 32 calories. Three and three-fourths hours were spent on the stationary bicycle, resulting in 9,653 revolutions of the pedals. This was calculated to produce 540,568 foot-pounds of work with a heat equivalent of 174

calories. Work was also performed upon the friction machine for six and one-fourth hours, during which time 25,000 revolutions were made and 735,000 foot-pounds, equivalent to 237 calories of energy, was measured. The total measured work during the six days was thus 2,745.718 foot-pounds per day. It seems certain that much more was actually performed. The amount of work done each day averaged four hours, which was about all the subject cared for. This induced fatigue.

The subject was very nearly in nitrogen equilibrium in the second rest period and in the third or work period. During the former there was a slight gain, and during the latter a slight loss of nitrogen each day.

In Table 46 the results obtained in the three periods are shown in detail.

*Details of experiment No. 13.*

*Subject.*—Chemist B, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 53.18 kilograms (117.3 pounds); at end of first period, 52.50 kilograms; at beginning of second period, 53.08 kilograms; at end of second period, 52.72 kilograms; at beginning of third period, 53.41 kilograms; at end of third period and experiment, 52.50 kilograms (115.7 pounds).

The experiment commenced with breakfast, November 29, 1898, and the first period continued two days. The second period commenced with breakfast, December 2, and continued three days. The third period commenced with breakfast, December 7, and continued six days.

TABLE 46.—*Results of experiment No. 13.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. TRIAL DIET. REST. (*Digestion experiment No. 111.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 425 | Milk | 3,000 | 477 | 21.60 | 135 | 199 | 143 | 24 | 3,069 |
| 426 | Oatmeal | 140 | 126 | 3.22 | 20 | 11 | 95 | 3 | 607 |
| 427 | Potato chips | 40 | 36 | .45 | 3 | 11 | 22 | 1 | 212 |
| 428 | Bread | 200 | 126 | 2.66 | 17 | 2 | 107 | 2 | 517 |
| 429 | Canned beef | 100 | 36 | 4.03 | 25 | 11 | ..... | 5 | 231 |
| 430 | Butter | 10 | 9 | .23 | ..... | 9 | ..... | ..... | 88 |
| 431 | Gelatin | 50 | 49 | .50 | 3 | ..... | 46 | ..... | 198 |
| ..... | Coffee | 250 | 1 | .10 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 200 | 200 | ..... | ..... | ..... | 200 | ..... | 792 |
| | Total | ..... | 1,060 | 32.79 | 204 | 243 | 613 | 35 | 5,714 |
| 434 | Feces | 56 | 40 | 1.92 | 12 | 15 | 13 | 16 | 309 |
| 435a | Urine | 1,730 | ..... | 22.84 | ..... | ..... | ..... | ..... | 240 |
| | Amount digested | ..... | 1,020 | 30.87 | 192 | 228 | 600 | 19 | 5,165 |
| | Coefficients of digestibility (per cent) | ..... | 96.2 | 94.1 | 94.1 | 93.8 | 97.9 | 54.3 | 90.4 |

TABLE 46.—*Results of experiment No. 13*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 112.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 436 | Milk | 2,787 | 441 | 20.90 | 131 | 181 | 129 | 22 | 2,912 |
| 426 | Oatmeal | 210 | 188 | 4.83 | 30 | 16 | 142 | 4 | 911 |
| 427 | Potato chips | 60 | 54 | .68 | 4 | 17 | 33 | 2 | 319 |
| 428 | Bread | 300 | 189 | 3.99 | 25 | 3 | 161 | 3 | 776 |
| 429 | Canned beef | 150 | 54 | 6.05 | 38 | 16 | ..... | 7 | 347 |
| 430 | Butter | 15 | 13 | .35 | ..... | 13 | ..... | ..... | 133 |
| 431 | Gelatin | 75 | 74 | .74 | 5 | ..... | 69 | ..... | 297 |
| ..... | Coffee | 375 | 1 | .15 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 300 | 300 | ..... | ..... | ..... | 300 | ..... | 1,188 |
| | Total | ..... | 1,314 | 37.69 | 234 | 246 | 834 | 38 | 6,883 |
| 438 | Feces | 80 | 64 | 3.49 | 22 | 20 | 22 | 16 | 416 |
| 439a | Urine | 2,447 | ..... | 34.47 | ..... | ..... | ..... | ..... | 265 |
| | Amount digested | ..... | 1,250 | 34.20 | 212 | 226 | 812 | 22 | 6,202 |
| | Coefficients of digestibility (per cent) | ..... | 95.1 | 90.6 | 90.6 | 91.9 | 97.4 | 57.9 | 90.1 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN ENERGY. REST. | | | | | | | | |
| | (*Digestion experiment No. 113.*) | | | | | | | | |
| 440 | Milk | 4,560 | 732 | 33.74 | 211 | 308 | 213 | 36 | 4,624 |
| 426 | Oatmeal | 420 | 377 | 9.66 | 60 | 32 | 285 | 8 | 1,822 |
| 427 | Potato chips | 240 | 218 | 2.71 | 17 | 68 | 133 | 9 | 1,274 |
| 428 | Bread | 948 | 597 | 12.61 | 79 | 10 | 508 | 8 | 2,452 |
| 429 | Canned beef | 300 | 108 | 12.09 | 76 | 32 | ..... | 14 | 693 |
| 430 | Butter | 240 | 213 | .55 | 4 | 209 | ..... | 7 | 2,122 |
| 431 | Gelatin | 150 | 148 | 1.49 | 9 | 1 | 138 | ..... | 594 |
| ..... | Coffee | 750 | 2 | .30 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 780 | 780 | ..... | ..... | ..... | 780 | ..... | 3,089 |
| | Total | ..... | 3,175 | 73.15 | 458 | 660 | 2.057 | 82 | 16,670 |
| 442 | Feces | 147 | 117 | 7.47 | 46 | 44 | 27 | 30 | 766 |
| 443a | Urine | 4,668 | ..... | 66.49 | ..... | ..... | ..... | ..... | 515 |
| | Amount digested | ..... | 3,058 | 65.68 | 412 | 616 | 2,030 | 52 | 15,389 |
| | Coefficients of digestibility (per cent) | ..... | 96.3 | 90.0 | 90.0 | 93.3 | 98.7 | 63.4 | 92.3 |

The total urine eliminated during the two days of the first rest period amounted to 1,730 grams, containing 1.32 per cent or 22.84 grams nitrogen.

The urine was collected in six-hour portions during the second rest period and the nitrogen determined by the usual method. The results are as follows:

TABLE 47.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 89).*

| | 8 a.m. to 2 p.m. | 2 p.m. to 8 p.m. | 8 p.m. to 2 a.m. | 2 a.m. to 8 a.m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 210 | 240 | 184 | 169 | 803 |
| Weight of nitrogen .....do.... | 2.58 | 2.88 | 3.16 | 2.52 | 11.14 |
| Per cent of nitrogen..... | 1.23 | 1.20 | 1.72 | 1.49 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 231 | 245 | 231 | 177 | 884 |
| Weight of nitrogen .....do.... | 2.80 | 3.04 | 3.44 | 2.46 | 11.74 |
| Per cent of nitrogen..... | 1.21 | 1.24 | 1.49 | 1.39 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 217 | 235 | 205 | 103 | 760 |
| Weight of nitrogen .....do.... | 2.95 | 3.34 | 3.34 | 1.96 | 11.59 |
| Per cent of nitrogen..... | 1.36 | 1.42 | 1.63 | 1.90 | ..... |

The urine was collected in six-hour portions during the third or work period and the nitrogen determined by the usual method. The results are as follows:

TABLE 48.—*Amount of nitrogen eliminated in the urine (digestion experiment No. 90).*

| | 8 a.m. to 2 p.m. | 2 p.m. to 8 p.m. | 8 p.m. to 2 a.m. | 2 a.m. to 8 a.m. | Total. |
|---|---|---|---|---|---|
| First day: | | | | | |
| Weight of urine.....grams.. | 161 | 224 | 103 | 143 | 631 |
| Weight of nitrogen .....do.... | 1.88 | 3.49 | 1.68 | 2.10 | 9.15 |
| Per cent of nitrogen..... | 1.17 | 1.56 | 1.63 | 1.47 | ..... |
| Second day: | | | | | |
| Weight of urine.....grams.. | 233 | 229 | 233 | 127 | 822 |
| Weight of nitrogen .....do.... | 3.24 | 3.41 | 3.77 | 2.30 | 12.72 |
| Per cent of nitrogen..... | 1.39 | 1.49 | 1.62 | 1.81 | ..... |
| Third day: | | | | | |
| Weight of urine.....grams.. | 215 | 300 | 214 | 144 | 873 |
| Weight of nitrogen .....do.... | 2.88 | 3.48 | 3.27 | 2.55 | 12.18 |
| Per cent of nitrogen..... | 1.34 | 1.16 | 1.53 | 1.77 | ..... |
| Fourth day: | | | | | |
| Weight of urine.....grams.. | 177 | 198 | 278 | 153 | 806 |
| Weight of nitrogen .....do.... | 2.53 | 2.57 | 3.81 | 2.39 | 11.30 |
| Per cent of nitrogen..... | 1.43 | 1.30 | 1.37 | 1.56 | ..... |
| Fifth day: | | | | | |
| Weight of urine.....grams.. | 209 | 226 | 198 | 160 | 793 |
| Weight of nitrogen .....do.... | 2.36 | 2.73 | 3.15 | 2.56 | 10.80 |
| Per cent of nitrogen..... | 1.13 | 1.21 | 1.59 | 1.60 | ..... |
| Sixth day: | | | | | |
| Weight of urine.....grams.. | 207 | 224 | 194 | 118 | 743 |
| Weight of nitrogen .....do.... | 2.44 | 2.71 | 3.20 | 1.99 | 10.34 |
| Per cent of nitrogen..... | 1.18 | 1.21 | 1.65 | 1.69 | ..... |
| Seventh day: | | | | | |
| Weight of urine.....grams.. | 289 | 459 | 155 | 251 | 1,154 |
| Weight of nitrogen .....do.... | 3.32 | 4.64 | 2.56 | 3.06 | 13.58 |
| Per cent of nitrogen..... | 1.15 | 1.01 | 1.65 | 1.22 | ..... |

The income and outgo of nitrogen is shown in Table 49, which records the average results for the three periods.

TABLE 49.—*Daily income and outgo of nitrogen in experiment No. 13.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−) |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet..... | 2 | 16.39 | 0.96 | 11.42 | +4.01 |
| Second period, rest, adjusted diet..... | 3 | 12.56 | 1.16 | 11.49 | − .09 |
| Third period, work, diet increased 484 calories ..... | 6 | 12.19 | 1.25 | 11.08 | − .14 |

## EXPERIMENT NO. 14.

This experiment, which was made with the same subject as experiment No. 11, was begun with breakfast January 24, 1899, and continued twelve days. The usual preliminary period preceded it, during which the subject selected the quantities of the different food materials which he thought most suited to his needs. The nitrogen balance was as usual determined approximately at the end of the first period (digestion experiment No. 114), and it was found that the subject was losing over 1.65 grams daily. Consequently the daily allowance of milk was increased by 263 grams and the second rest period (digestion experiment No. 115) began with breakfast January 27 and continued three days. Although but 1.34 grams of nitrogen were added to the daily diet during this period and the subject had lost nitrogen during the first rest period, there was now a gain of 0.71 gram nitrogen per day during this latter period. The body weight of the subject remained practically constant.

No interval elapsed between the second rest period and the third or work period (digestion experiment No. 116). The diet was changed, beginning with breakfast January 30, by allowing 50 grams of sugar, 36 grams of butter, and 50 grams of bread daily in excess of that consumed in the previous period. In order to avoid increasing the nitrogen in the diet the daily allowance of milk was decreased by 160 grams. The total increase in the energy was 626 calories and the decrease in the milk 128 calories, making a net increase of 593 calories per day. The character of the work performed in this experiment was the same as in No. 13 and the amount was not far different. Seventeen hours were spent in making 85 trips up and down hill; according to the method of calculation followed, this sufficed for the production of 1,789,547 foot-pounds, equivalent to 577 calories of heat. The subject worked the stationary bicycle for five hours, making 10,000 revolutions of the pedals. This was calculated to produce 480,000 foot-pounds of work, equivalent to 155 calories. He also worked three hours with the friction machine, which measured 289,442 foot-pounds, the heat equivalent of which is 93 calories. The total measured work during the six days of this experiment thus amounted to 2,558,989 foot-pounds or 352,964 kilogrammeters, equivalent to 825 calories of energy or an average of 138 calories per day. As previously stated, the amount measured must have been much less than the amount performed. The subject worked an average of four hours and ten minutes each day. His body weight during the six days remained constant, although there was a loss of 1.1 grams of nitrogen per day.

The following table shows the results of the experiment:

*Details of experiment No. 14.*

*Subject.*—Student.

*Weight (without clothing).*—At beginning of experiment, 68.18 kilograms (150.4 pounds); at end of first period, 67.27 kilograms; at beginning of second period, 67.50

kilograms; at end of second period, 67.27 kilograms; at beginning of third period, 67.27 kilograms; at end of third period and experiment, 67.27 kilograms (148.4 pounds).

The experiment commenced with breakfast January 24, 1899, and the first period continued two days. The second period commenced with breakfast January 27 and continued three days. The third period commenced with breakfast January 30 and continued six days.

TABLE 50.—*Results of experiment No. 14.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 114.*) | | | | | | | | |
| | | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 444 | Milk | 3,000 | 341 | 15.30 | 96 | 104 | 141 | 23 | 1,959 |
| 445 | Oatmeal | 140 | 126 | 3.60 | 22 | 11 | 93 | 3 | 618 |
| 446 | Potato chips | 50 | 46 | .56 | 4 | 17 | 25 | 2 | 280 |
| 447 | Bread | 300 | 197 | 4.35 | 27 | 3 | 167 | 3 | 851 |
| 448 | Beef | 150 | 59 | 6.15 | 38 | 21 | ..... | 6 | 388 |
| 449 | Eggs | 188 | 45 | 3.91 | 24 | 21 | ..... | 2 | 336 |
| 450 | Butter | 10 | 8 | .02 | ..... | 8 | ..... | ..... | 78 |
| 451 | Gelatin | 50 | 49 | .51 | 3 | ..... | 46 | ..... | 199 |
| ..... | Coffee | 200 | 1 | .08 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 100 | 100 | ..... | ..... | ..... | 100 | ..... | 396 |
| | Total | ..... | 972 | 34.48 | 215 | 185 | 572 | 39 | 5,105 |
| 452 | Feces | 58 | 42 | 2.89 | 18 | 13 | 11 | 16 | 265 |
| 455 | Urine | 2,406 | ..... | 34.89 | ..... | ..... | ..... | ..... | 246 |
| | Amount digested | ..... | 930 | 31.59 | 197 | 172 | 561 | 23 | 4,594 |
| | Coefficients of digestibility (per cent) | ..... | 95.7 | 91.6 | 91.6 | 93.0 | 98.1 | 59.0 | 90.0 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 115.*) | | | | | | | | |
| 456 | Milk | 5,289 | 592 | 26.97 | 169 | 178 | 245 | 40 | 3,359 |
| 445 | Oatmeal | 210 | 190 | 5.40 | 34 | 16 | 140 | 4 | 928 |
| 446 | Potato chips | 75 | 69 | .84 | 5 | 26 | 38 | 3 | 420 |
| 447 | Bread | 450 | 296 | 6.53 | 40 | 5 | 251 | 4 | 1,277 |
| 448 | Beef | 225 | 89 | 9.23 | 58 | 31 | ..... | 9 | 582 |
| 449 | Eggs | 282 | 68 | 5.87 | 37 | 31 | ..... | 3 | 504 |
| 450 | Butter | 15 | 13 | .03 | ..... | 13 | ..... | ..... | 118 |
| 451 | Gelatin | 75 | 74 | .76 | 5 | 1 | 68 | ..... | 298 |
| ..... | Coffee | 300 | 1 | .12 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 150 | 150 | ..... | ..... | ..... | 150 | ..... | 594 |
| | Total | ..... | 1,542 | 55.75 | 349 | 301 | 892 | 63 | 8,080 |
| 457 | Feces | 69 | 49 | 2.99 | 19 | 14 | 16 | 20 | 317 |
| 460 | Urine | 4,561 | ..... | 50.63 | ..... | ..... | ..... | ..... | 412 |
| | Amount digested | ..... | 1,493 | 52.76 | 330 | 287 | 876 | 43 | 7,351 |
| | Coefficients of digestibility (per cent) | ..... | 96.8 | 94.6 | 94.6 | 95.4 | 98.2 | 68.3 | 91.0 |

TABLE 50.—*Results of experiment No. 14*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | THIRD PERIOD. DIET INCREASED IN ENERGY. WORK. (*Digestion experiment No. 116.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 461 | Milk | 9,618 | 1,130 | 48.09 | 301 | 367 | 462 | 71 | 6,540 |
| 445 | Oatmeal | 420 | 379 | 10.79 | 67 | 33 | 279 | 8 | 1,855 |
| 446 | Potato chips | 150 | 138 | 1.68 | 11 | 51 | 76 | 5 | 840 |
| 447 | Bread | 1,200 | 790 | 17.40 | 108 | 13 | 669 | 12 | 3,406 |
| 448 | Beef | 450 | 178 | 18.45 | 115 | 63 | ..... | 17 | 1,164 |
| 449 | Eggs | 564 | 136 | 11.73 | 73 | 63 | ..... | 6 | 1,008 |
| 450 | Butter | 246 | 208 | .49 | 3 | 205 | ..... | 7 | 1,929 |
| 451 | Gelatin | 150 | 148 | 1.52 | 9 | 2 | 137 | ..... | 596 |
| ..... | Coffee | 600 | 2 | .24 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 600 | 600 | ..... | ..... | ..... | 600 | ..... | 2,376 |
| | Total | ..... | 3,709 | 110.39 | 689 | 797 | 2,223 | 126 | 19,714 |
| 462 | Feces | 161 | 116 | 6.94 | 43 | 37 | 36 | 45 | 789 |
| 465 | Urine | 7,338 | ..... | 110.07 | ..... | ..... | ..... | ..... | 807 |
| | Amount digested | ..... | 3,593 | 103.45 | 646 | 760 | 2,187 | 81 | 18,118 |
| | Coefficients of digestibility (per cent) | ..... | 96.9 | 93.8 | 93.8 | 95.4 | 98.4 | 64.3 | 91.9 |

During the four days of the first rest period the total elimination of urine amounted to 2,406 grams with 1.45 per cent, or 34.89 grams, nitrogen.

The previous experiments had shown that there was little or no increased elimination of nitrogen in the urine during the work periods. In the earlier experiments of this series the urine had been collected in portions corresponding to six-hour intervals during the second rest period and the work period, in order that some light might be thrown on the nitrogen lag by the change in the elimination of nitrogen in the different periods of the experiment, if any were found. Since no marked change was observed it was not thought necessary to increase the analytical labor, which at best was great, by continuing this practice. Consequently in the remaining experiments the urine was collected for the whole periods and the nitrogen was determined in a composite sample. The urine during the second rest period amounted to 4,561 grams with 1.11 per cent, or 50.63 grams, nitrogen.

The total urine for the six days of the work period amounted to 7,338 grams, containing 1.50 per cent, or 110.07 grams, nitrogen.

From the data recorded above and in Tables Nos. 1 and 2 the average daily balance of income and outgo of nitrogen was calculated.

TABLE 51.—*Daily income and outgo of nitrogen in experiment No. 14.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain (+), loss (−). |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, rest, trial diet | 2 | 17.24 | 1.45 | 17.44 | −1.65 |
| Second period, rest, adjusted diet | 3 | 18.58 | 1.00 | 16.87 | + .71 |
| Third period, work, diet increased 593 calories | 6 | 18.40 | 1.16 | 18.34 | −1.10 |

## EXPERIMENT NO. 15.

This experiment was coincident with experiment No. 14 and was made with the same subject as Nos. 9 and 12. The first rest period (digestion experiment No. 117) began with breakfast January 24, 1899, and covered two days. A slight loss of nitrogen was found. The daily allowance of milk was therefore increased 114 grams per day and the second rest period (digestion experiment No. 118) began with breakfast January 27. In spite of the additional nitrogen in the diet there was still a slight loss, amounting to 0.2 gram per day. This is so little that the subject was considered to be practically in nitrogen equilibrium.

There was no interval between the second rest period and the third, or work, period. Fifty grams of bread, 36 of butter, and 50 of sugar were added to the daily ration and the allowance of milk was diminished by 160 grams. The net energy added to the diet amounted to 608 calories. During the work period (digestion experiment No. 119) 87 trips were made up and down hill, occupying seventeen and one-half hours, calculated to produce 1,878,069 foot-pounds of work, equivalent to 606 calories. Four hours were spent upon the stationary bicycle, giving 8,000 revolutions of the pedals. This was calculated to produce 384,000 foot-pounds of work, equivalent to 124 calories. The time spent with the friction machine was three and one-half hours. The work measured was 329,280 foot-pounds, equivalent to 106 calories. The total amount of work measured therefore amounted to 2,591,349 foot-pounds, or 357,428 kilogrammeters, the heat equivalent of which is 836 calories, or an average of 138 calories per day. This must have been considerably less than the amount actually produced.

During the work period there was a daily loss of only 0.27 gram nitrogen, the subject being nearly in nitrogen equilibrium.

The results for the three periods are shown in the table which follows.

*Details of experiment No. 15.*

*Subject.*—Chemist A, 29 years of age.

*Weight (without clothing).*—At beginning of experiment, 69.09 kilograms (152.3 pounds); at end of first period, 68.64 kilograms; at beginning of second period, 68.18 kilograms; at end of second period, 67.73 kilograms; at beginning of third period, 67.73 kilograms; at end of third period and experiment, 67.73 kilograms (149.3 pounds).

The experiment commenced with breakfast January 24, 1899, and the first period continued two days. The second period commenced with breakfast January 27 and continued three days. The third period commenced with breakfast January 30 and continued six days.

TABLE 52.—*Results of experiment No. 15.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. | | | | | | | | |
| | TRIAL DIET. REST. | | | | | | | | |
| | (*Digestion experiment No. 117.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 441 | Milk | 4,000 | 455 | 20.40 | 128 | 139 | 188 | 30 | 2,612 |
| 445 | Oatmeal | 140 | 126 | 3.60 | 22 | 11 | 93 | 3 | 618 |
| 446 | Potato chips | 20 | 18 | .22 | 1 | 7 | 10 | 1 | 112 |
| 447 | Bread | 400 | 263 | 5.80 | 36 | 4 | 223 | 4 | 1,135 |
| 448 | Beef | 100 | 40 | 4.10 | 26 | 14 | ..... | 4 | 259 |
| 449 | Eggs | 196 | 47 | 4.08 | 25 | 22 | ..... | 2 | 350 |
| 450 | Butter | 10 | 8 | .02 | ..... | 8 | ..... | ..... | 78 |
| 451 | Gelatin | 50 | 49 | .51 | 3 | ..... | 46 | ..... | 199 |
| ..... | Coffee | 800 | 2 | .32 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 100 | 100 | ..... | ..... | ..... | 100 | ..... | 396 |
| | Total | ..... | 1,108 | 39.05 | 243 | 205 | 660 | 44 | 5,759 |
| 453 | Feces | 54 | 38 | 2.67 | 17 | 9 | 12 | 16 | 230 |
| 455a | Urine | 3,610 | ..... | 37.18 | ..... | ..... | ..... | ..... | 282 |
| | Amount digested | ..... | 1,070 | 36.38 | 226 | 196 | 648 | 28 | 5,247 |
| | Coefficients of digestibility (per cent) | ..... | 96.6 | 93.0 | 93.0 | 95.6 | 98.2 | 63.6 | 91.1 |
| | SECOND PERIOD. | | | | | | | | |
| | DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. | | | | | | | | |
| | (*Digestion experiment No. 118.*) | | | | | | | | |
| 456 | Milk | 6,342 | 710 | 32.34 | 202 | 214 | 294 | 48 | 4,027 |
| 445 | Oatmeal | 210 | 190 | 5.40 | 34 | 16 | 140 | 4 | 928 |
| 446 | Potato chips | 30 | 27 | .34 | 2 | 10 | 15 | 1 | 168 |
| 447 | Bread | 600 | 395 | 8.70 | 54 | 7 | 334 | 6 | 1,703 |
| 448 | Beef | 150 | 59 | 6.15 | 38 | 21 | ..... | 6 | 388 |
| 449 | Eggs | 294 | 71 | 6.12 | 38 | 33 | ..... | 3 | 525 |
| 450 | Butter | 15 | 13 | .03 | ..... | 13 | ..... | ..... | 118 |
| 451 | Gelatin | 75 | 74 | .76 | 5 | 1 | 68 | ..... | 298 |
| ..... | Coffee | 1,200 | 3 | .48 | 3 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 150 | 150 | ..... | ..... | ..... | 150 | ..... | 594 |
| | Total | ..... | 1,692 | 60.32 | 376 | 315 | 1,001 | 68 | 8,749 |
| 458 | Feces | 85 | 58 | 4.04 | 25 | 15 | 18 | 26 | 360 |
| 460a | Urine | 6,322 | ..... | 56.90 | ..... | ..... | ..... | ..... | 439 |
| | Amount digested | ..... | 1,634 | 56.28 | 351 | 300 | 983 | 42 | 7,950 |
| | Coefficients of digestibility (per cent) | ..... | 96.6 | 93.4 | 93.4 | 95.2 | 98.2 | 61.8 | 90.9 |
| | THIRD PERIOD. | | | | | | | | |
| | DIET INCREASED IN ENERGY. WORK. | | | | | | | | |
| | (*Digestion experiment No. 119.*) | | | | | | | | |
| 461 | Milk | 11,724 | 1,378 | 58.62 | 367 | 448 | 563 | 87 | 7,972 |
| 445 | Oatmeal | 420 | 379 | 10.79 | 67 | 33 | 279 | 8 | 1,855 |
| 446 | Potato chips | 60 | 55 | .67 | 4 | 21 | 30 | 2 | 336 |
| 447 | Bread | 1,500 | 988 | 21.75 | 135 | 17 | 836 | 15 | 4,257 |
| 448 | Beef | 300 | 119 | 12.30 | 77 | 42 | ..... | 11 | 776 |
| 449 | Eggs | 588 | 142 | 12.23 | 76 | 66 | ..... | 6 | 1,051 |
| 450 | Butter | 246 | 208 | .49 | 3 | 205 | ..... | 7 | 1,929 |
| 451 | Gelatin | 150 | 148 | 1.52 | 9 | 2 | 137 | ..... | 596 |
| ..... | Coffee | 2,400 | 6 | .96 | 6 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 600 | 600 | ..... | ..... | ..... | 600 | ..... | 2,376 |
| | Total | ..... | 4,023 | 119.33 | 744 | 834 | 2,445 | 136 | 21,148 |
| 463 | Feces | 180 | 131 | 8.39 | 52 | 35 | 44 | 49 | 845 |
| 465a | Urine | 8,279 | ..... | 112.59 | ..... | ..... | ..... | ..... | 865 |
| | Amount digested | ..... | 3,892 | 110.94 | 692 | 799 | 2,401 | 87 | 19,438 |
| | Coefficients of digestibility (per cent) | ..... | 96.7 | 93.0 | 93.0 | 95.8 | 98.2 | 64.0 | 91.9 |

During the two days of the first rest period the urine amounted to 3,610 grams, and contained 1.03 per cent, or 37.18 grams, nitrogen.

The total urine for the three days of the second rest period amounted to 6,322 grams, with 0.90 per cent, or 56.90 grams, nitrogen.

For reasons already given, the urine was not collected in portions corresponding to six-hour intervals, but in one portion for the whole period, which amounted to 8,279 grams, and contained 1.36 per cent, or 112.59 grams, nitrogen.

Following the same methods as in previous experiments, the average daily balance of income and outgo of nitrogen was calculated as follows:

TABLE 53.—*Daily income and outgo of nitrogen in experiment No. 15.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Loss. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Gram.* |
| First period, rest, trial diet | 2 | 19.52 | 1.33 | 18.59 | 0.40 |
| Second period, rest, adjusted diet | 3 | 20.11 | 1.35 | 18.97 | .21 |
| Third period, work, diet increased 609 calories | 6 | 19.89 | 1.40 | 18.76 | .27 |

## EXPERIMENT NO. 16.

This experiment, which was coincident with experiment No. 15, was made with the same subject as experiments Nos. 10 and 13. During the two days of the first rest period (digestion experiment No. 120) there was a gain of nitrogen amounting to 3.3 grams per day. The diet was consequently decreased by diminishing the daily allowance of milk 467 grams and the eggs 47 grams. During the second rest period (digestion experiment No. 121), which continued three days, beginning with breakfast January 27, there was still a slight gain of nitrogen amounting to nearly 0.3 of a gram per day. The subject, however, may be regarded as practically in nitrogen equilibrium.

The work period (digestion experiment No. 122) began with breakfast January 30 and continued six days. The daily diet was increased by adding 38 grams of sugar, 37 grams of butter, 10 grams of potato chips, and 63 grams of bread. In order to avoid an increase of nitrogen the allowance of milk was diminished 220 grams per day. The net increase in energy amounted to 570 calories per day. The character of the work performed was the same as in the previous experiments. Nineteen hours were spent in making 95 trips up and down hill with the production, as calculated, of 1,645,636 foot-pounds of work, the heat equivalent of which is 531 calories; four hours were spent upon the stationary bicycle, giving 8,000 revolutions of the pedals, and four hours upon the friction machine, giving 13,000 revolutions. The measured work upon the stationary bicycle amounted to 384,000 foot-pounds and upon the friction machine to 382,200 foot-pounds. The heat equivalent of the work performed upon these two machines was 124 and 123 calories, respectively. During the six days of the experiment, therefore, a total of twenty-seven hours was spent in active

muscular work. The total measured amount was equal to 2,411,836 foot-pounds, or 332,667 kilogrammeters, the heat equivalent of which is 778 calories, or an average of 130 calories per day. The amount actually produced must have been much more. The results of the experiment are shown in the following table:

*Details of experiment No. 16.*

*Subject.*—Chemist B, 22 years of age.

*Weight (without clothing).*—At beginning of experiment, 54.09 kilograms (119.3 pounds); at end of first period, 53.95 kilograms; at beginning of second period, 53.86 kilograms; at end of second period, 53.64 kilograms; at beginning of third period, 53.64 kilograms; at end of third period and experiment, 53.19 kilograms (117.3 pounds).

The experiment commenced with breakfast January 24, 1899, and the first period continued two days. The second period commenced with breakfast January 27 and continued three days. The third period commenced with breakfast January 30 and continued six days.

TABLE 54.—*Results of experiment No. 16.*

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | FIRST PERIOD. TRIAL DIET. REST. (*Digestion experiment No. 120.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 444 | Milk | 3,200 | 364 | 16.32 | 102 | 111 | 151 | 24 | 2,090 |
| 445 | Oatmeal | 140 | 126 | 3.60 | 22 | 11 | 93 | 3 | 618 |
| 446 | Potato chips | 40 | 37 | .45 | 3 | 14 | 20 | 1 | 224 |
| 447 | Bread | 200 | 132 | 2.90 | 18 | 2 | 112 | 2 | 568 |
| 448 | Beef | 100 | 40 | 4.10 | 26 | 14 | ..... | 4 | 259 |
| 449 | Eggs | 189 | 46 | 3.93 | 25 | 21 | ..... | 2 | 338 |
| 450 | Butter | 10 | 8 | .02 | ..... | 8 | ..... | ..... | 78 |
| 451 | Gelatin | 50 | 49 | .51 | 3 | ..... | 46 | ..... | 199 |
| ..... | Coffee | 200 | 1 | .08 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 200 | 200 | ..... | ..... | ..... | 200 | ..... | 792 |
| | Total | ..... | 1,003 | 31.91 | 200 | 181 | 622 | 36 | 5,166 |
| 454 | Feces | 50 | 38 | 2.31 | 14 | 10 | 14 | 12 | 241 |
| 455b | Urine | 2,803 | ..... | 22.98 | ..... | ..... | ..... | ..... | 232 |
| | Amount digested | ..... | 965 | 29.60 | 186 | 171 | 608 | 24 | 4,693 |
| | Coefficients of digestibility (per cent) | ..... | 96.2 | 93.0 | 93.0 | 94.5 | 97.7 | 66.7 | 90.8 |
| | SECOND PERIOD. DIET ADJUSTED FOR NITROGEN EQUILIBRIUM. REST. (*Digestion experiment No. 121.*) | | | | | | | | |
| 456 | Milk | 3,399 | 381 | 17.33 | 108 | 115 | 158 | 25 | 2,158 |
| 445 | Oatmeal | 210 | 190 | 5.40 | 34 | 16 | 140 | 4 | 928 |
| 446 | Potato chips | 60 | 55 | .67 | 4 | 21 | 30 | 2 | 336 |
| 447 | Bread | 300 | 197 | 4.35 | 27 | 3 | 167 | 3 | 851 |
| 448 | Beef | 150 | 59 | 6.15 | 38 | 21 | ..... | 6 | 388 |
| 449 | Eggs | 144 | 35 | 3.00 | 19 | 16 | ..... | 1 | 257 |
| 450 | Butter | 15 | 13 | .03 | ..... | 13 | ..... | ..... | 118 |
| 451 | Gelatin | 75 | 74 | .76 | 5 | 1 | 68 | ..... | 298 |
| ..... | Coffee | 300 | 1 | .12 | 1 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 300 | 300 | ..... | ..... | ..... | 300 | ..... | 1,188 |
| | Total | ..... | 1,305 | 37.81 | 236 | 206 | 863 | 41 | 6,522 |
| 459 | Feces | 51 | 38 | 2.50 | 16 | 6 | 16 | 13 | 243 |
| 460b | Urine | 3,048 | ..... | 34.44 | ..... | ..... | ..... | ..... | 275 |
| | Amount digested | ..... | 1,267 | 35.31 | 220 | 200 | 847 | 28 | 6,004 |
| | Coefficients of digestibility (per cent) | ..... | 97.1 | 93.2 | 93.2 | 97.1 | 98.2 | 68.3 | 92.0 |

TABLE 54.—*Results of experiment No. 16*—Continued.

| Laboratory number. | | Weight of material. | Total organic matter. | Nitrogen. | Protein (N × 6.25). | Fat. | Carbohydrates. | Ash. | Heat of combustion determined. |
|---|---|---|---|---|---|---|---|---|---|
| | THIRD PERIOD. DIET INCREASED IN ENERGY. WORK. (*Digestion experiment No. 122.*) | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* |
| 461 | Milk | 5,478 | 643 | 27.39 | 171 | 209 | 263 | 41 | 3,725 |
| 445 | Oatmeal | 420 | 380 | 10.79 | 68 | 33 | 279 | 8 | 1,855 |
| 446 | Potato chips | 180 | 166 | 2.02 | 13 | 62 | 91 | 6 | 1,008 |
| 447 | Bread | 978 | 644 | 14.18 | 88 | 11 | 545 | 9 | 2,776 |
| 448 | Beef | 300 | 119 | 12.30 | 77 | 42 | ..... | 11 | 776 |
| 449 | Eggs | 288 | 69 | 5.99 | 37 | 32 | ..... | 3 | 515 |
| 450 | Butter | 252 | 213 | .50 | 3 | 210 | ..... | 7 | 1,976 |
| 451 | Gelatin | 150 | 148 | 1.52 | 9 | 2 | 137 | ..... | 596 |
| ..... | Coffee | 600 | 2 | .24 | 2 | ..... | ..... | ..... | ..... |
| ..... | Sugar | 828 | 828 | ..... | ..... | ..... | 828 | ..... | 3,279 |
| | Total | ..... | 3,212 | 74.93 | 468 | 601 | 2,143 | 85 | 16,506 |
| 464 | Feces | 124 | 99 | 6.66 | 42 | 29 | 28 | 25 | 637 |
| 465b | Urine | 5,360 | ..... | 64.86 | ..... | ..... | ..... | ..... | 533 |
| | Amount digested | ..... | 3,113 | 68.27 | 426 | 572 | 2,115 | 60 | 15,336 |
| | Coefficients of digestibility (per cent) | ..... | 96.9 | 91.0 | 91.0 | 95.2 | 98.7 | 70.6 | 92.9 |

There was an elimination of 2,803 grams of urine during the two days of the first rest period, with 0.82 per cent or 22.98 grams of nitrogen.

The urine for the second rest period amounted to 3,048 grams, with 1.13 per cent or 34.44 grams nitrogen.

As in the two previous metabolism experiments, the urine was not collected in portions corresponding to six-hour intervals in the work period. The total urine for the six days amounted to 5,360 grams and contained 1.21 per cent or 64.86 grams nitrogen.

Table 55 shows the average daily balance of income and outgo of nitrogen in the three periods of experiment No. 16.

TABLE 55.—*Daily income and outgo of nitrogen in experiment No. 16.*

| | Time. | Nitrogen. | | | |
|---|---|---|---|---|---|
| | | In food. | In feces. | In urine. | Gain. |
| | *Days.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| First period, trial diet, rest | 2 | 15.96 | 1.16 | 11.49 | 3.31 |
| Second period, adjusted diet, rest | 3 | 12.60 | .83 | 11.48 | .29 |
| Third period, work, diet increased 577 calories | 6 | 12.49 | 1.11 | 10.81 | .47 |

## SUMMARY OF RESULTS OBTAINED IN 1898–99.

### INCOME AND OUTGO OF NITROGEN.

In Table 56 the results obtained in the different periods of experiments Nos. 9–16 are briefly summarized. The average daily income and outgo of nitrogen are shown, as well as the total and available energy in all the periods and the amount of external muscular work actually measured during the work period.

TABLE 56.—*Daily income and outgo of nitrogen and energy in metabolism experiments Nos. 9–16, with work actually measured.*

| Metabolism experiment No. | Digestion experiment No. | Character of experiment. | Subject. | Average loss in body weight. | Nitrogen. | | | | Energy. | | | | External muscular work measured. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | In food. | In feces. | In urine. | Gain (+), or loss (−). | In food. | In feces. | In urine. | Available. | Amount. | Heat equivalent. |
| | | | | *Kg.* | *Gms.* | *Gms.* | *Gms.* | *Gms.* | *Calories.* | *Calories.* | *Calories.* | *Calories.* | *Kgs.* | *Calories.* |
| 9 | 99 | Rest .... | B | 0.45 | 19.80 | 1.46 | 19.39 | −1.05 | 3,113 | 164 | 144 | 2,805 | ..... | ..... |
| | 100 | ...do .... | B | .15 | 20.65 | 1.64 | 22.13 | −3.12 | 3,232 | 184 | 148 | 2,900 | ..... | ..... |
| | 101 | Work ... | B | .00 | 20.61 | 1.55 | 17.85 | +1.21 | 3,861 | 180 | 149 | 3,532 | 54,359 | 127 |
| 10 | 102 | Rest .... | D | .35 | 14.72 | 1.31 | 10.21 | +3.20 | 2,614 | 188 | 105 | 2,321 | ..... | ..... |
| | 103 | ...do .... | D | .07 | 11.31 | 1.18 | 11.40 | −1.27 | 2,126 | 130 | 79 | 1,917 | ..... | ..... |
| | 104 | Work ... | D | .06 | 11.25 | 1.13 | 9.71 | + .41 | 2,723 | 124 | 79 | 2,520 | 56,339 | 132 |
| 11 | 105 | Rest .... | E | .52 | 16.77 | 1.13 | 10.48 | +5.16 | 2,828 | 177 | 122 | 2,529 | ..... | ..... |
| | 106 | ...do .... | E | .14 | 11.57 | .91 | 11.70 | −1.04 | 2,094 | 122 | 83 | 1,889 | ..... | ..... |
| | 107 | Work ... | E | .05 | 11.51 | .92 | 10.93 | − .34 | 2,658 | 121 | 83 | 2,454 | 62,951 | 147 |
| 12 | 108 | Rest .... | B | .71 | 21.19 | 1.52 | 20.75 | −1.08 | 3,551 | 179 | 152 | 3,020 | ..... | ..... |
| | 109 | ...do .... | B | .00 | 22.16 | 1.64 | 21.39 | − .87 | 3,486 | 185 | 160 | 3,141 | ..... | ..... |
| | 110 | Work ... | B | .00 | 21.86 | 1.62 | 19.93 | + .31 | 3,943 | 185 | 158 | 3,600 | 62,713 | 147 |
| 13 | 111 | Rest .... | D | .34 | 16.39 | .96 | 11.42 | +4.01 | 2,857 | 154 | 120 | 2,583 | ..... | ..... |
| | 112 | ....do ... | D | .12 | 12.56 | 1.16 | 11.49 | − .09 | 2,294 | 139 | 88 | 2,067 | ..... | ..... |
| | 113 | Work ... | D | .15 | 12.19 | 1.25 | 11.08 | − .14 | 2,778 | 127 | 86 | 2,565 | 63,120 | 148 |
| 14 | 114 | Rest .... | E | .91 | 17.24 | 1.45 | 17.44 | −1.65 | 2,552 | 132 | 123 | 2,297 | ..... | ..... |
| | 115 | ....do ... | E | .23 | 18.58 | 1.00 | 16.87 | + .71 | 2,693 | 106 | 137 | 2,450 | ..... | ..... |
| | 116 | Work ... | E | .00 | 18.40 | 1.16 | 18.34 | −1.10 | 3,286 | 131 | 135 | 3,020 | 58,827 | 138 |
| 15 | 117 | Rest .... | B | .35 | 19.52 | 1.33 | 18.59 | − .40 | 2,880 | 115 | 141 | 2,624 | ..... | ..... |
| | 118 | ....do ... | B | .45 | 20.11 | 1.35 | 18.97 | − .21 | 2,916 | 120 | 146 | 2,650 | ..... | ..... |
| | 119 | Work ... | B | .00 | 19.89 | 1.40 | 18.76 | − .27 | 3,525 | 141 | 144 | 3,240 | 59,571 | 139 |
| 16 | 120 | Rest .... | D | .14 | 15.96 | 1.16 | 11.49 | +3.31 | 2,583 | 120 | 116 | 2,347 | ..... | ..... |
| | 121 | ....do ... | D | .22 | 12.60 | .83 | 11.48 | + .29 | 2,174 | 81 | 91 | 2,002 | ..... | ..... |
| | 122 | Work ... | D | .45 | 12.49 | 1.11 | 10.81 | + .47 | 2,751 | 106 | 88 | 2,557 | 55,444 | 130 |
| | Average, first rest period .. | | | | 17.70 | 1.29 | 14.97 | +1.44 | 2,847 | 154 | 128 | 2,566 | ..... | ..... |
| | Average, second rest period ..... | | | | 16.19 | 1.21 | 15.68 | − .70 | 2,627 | 133 | 117 | 2,378 | ..... | ..... |
| | Average, work period ..... | | | | 16.03 | 1.27 | 14.68 | + .80 | 3,191 | 139 | 115 | 2,936 | 59,153 | 139 |

The amount of nitrogen in the food during the second rest period and the third or work period immediately following was practically the same in all the experiments of this series. When variations were greatest, the nitrogen in the food was from 0.3 to 0.4 gram less per day in the work period than in the preceding rest period. It will be noticed, however, that if there was a gain of nitrogen during the rest period as a rule the gain was increased during the work period, and if there was a loss of nitrogen during the rest period the loss was generally diminished during the work period. The energy furnished by the diet in the work period was considerably greater than in the rest

period, and the nitrogen in the food was practically the same in the two periods. The amount of work calculated or actually measured was much larger in these experiments than in those of the previous year and the muscular activity was as great as the subjects cared to undertake. The duration of the work averaged about four hours each day, and as calculated the heat equivalent of the muscular work performed was on the average not far from 35 calories per hour.

The effect of muscular work on the excretion of nitrogen is discussed at greater length when the results of the two series of experiments are considered (p. 73.)

## CONCLUSIONS FROM THE TWO SERIES OF EXPERIMENTS.

The experiments here reported have had in view the study of the changes (if any) which occurred in the digestibility of a simple mixed diet and in the daily excretion of nitrogen in the urine when the experimental condition changed from comparative rest to more or less active muscular exertion. The two series of experiments were alike in that each included two periods of rest and one of muscular work. The attempt was made to bring the subject into nitrogen equilibrium during the first rest period, or at least during the rest period immediately preceding the work period. The diet was increased during the work period chiefly by the addition of fats and carbohydrates. The amount was sufficient to furnish the energy it was calculated would be required for the muscular work performed. The experiments in the two series differed as regards the length of the periods, and more especially as regards the quantities of protein and energy in the food and the kind and amount of muscular work done. Individual tests were repeated to some extent, either by duplicating the tests with the same man or by making duplicate or triplicate experiments at the same time with different men.

### THE DIGESTIBILITY OF NUTRIENTS.

The data obtained under the different experimental conditions serve for computation of the proportions of protein, fat, carbohydrates, and energy in the food eaten which were actually available for use in the body. In Table 57 are summarized the coefficients of digestibility found in the different experiments in the series reported above.

TABLE 57.—*Summary of coefficients of digestibility of a simple mixed diet and the energy available.*

| Number of experiment. | Subject. | Character of experiment. | Protein. | Fat. | Carbohydrates. | Energy. |
|---|---|---|---|---|---|---|
| | | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 53 | A | Rest | 94.4 | 96.9 | 96.2 | 90.8 |
| 54 | A | Rest | 94.9 | 96.7 | 96.2 | 90.6 |
| 55 | A | Work | 96.2 | 95.9 | 98.7 | 92.4 |
| 56 | B | Rest | 94.2 | 94.9 | 98.1 | 90.8 |
| 57 | B | Rest | 94.5 | 96.4 | 97.6 | 90.9 |
| 58 | B | Work | 94.8 | 95.2 | 98.9 | 91.7 |
| 59 | C | Rest | 94.2 | 94.9 | 96.5 | 88.9 |
| 60 | C | Rest | 94.8 | 96.3 | 97.3 | 90.1 |
| 61 | C | Work | 91.2 | 94.0 | 98.0 | 91.1 |
| 62 | A | Rest | 91.7 | 97.1 | 95.9 | 91.2 |
| 63 | A | Rest | 94.9 | 97.6 | 97.6 | 92.4 |
| 64 | A | Work | 94.0 | 97.8 | 97.5 | 92.8 |
| 65 | B | Rest | 93.3 | 96.7 | 97.6 | 91.1 |
| 66 | B | Rest | 93.3 | 95.7 | 97.9 | 91.5 |
| 67 | B | Work | 92.4 | 94.5 | 98.4 | 91.5 |
| 68 | C | Rest | 95.1 | 96.7 | 96.6 | 91.1 |
| 69 | C | Work | 94.5 | 97.7 | 96.8 | 92.0 |
| 70 | A | Rest | 96.1 | 97.4 | 96.8 | 91.2 |
| 71 | A | Rest | 95.8 | 96.4 | 96.9 | 90.8 |
| 72 | A | Work | 96.1 | 97.5 | 97.6 | 92.1 |
| 73 | B | Rest | 95.3 | 95.3 | 98.1 | 90.6 |
| 74 | B | Rest | 94.6 | 95.5 | 96.8 | 89.9 |
| 75 | B | Work | 94.4 | 95.2 | 97.8 | 91.0 |
| 99 | B | Rest | 92.7 | 95.7 | 96.8 | 90.0 |
| 100 | B | Rest | 92.0 | 96.2 | 96.2 | 89.7 |
| 101 | B | Work | 92.5 | 95.0 | 97.9 | 91.5 |
| 102 | D | Rest | 91.4 | 88.2 | 98.2 | 88.8 |
| 103 | D | Rest | 89.6 | 91.0 | 98.3 | 90.2 |
| 104 | D | Work | 89.8 | 93.1 | 99.0 | 92.5 |
| 105 | E | Rest | 92.9 | 95.5 | 96.1 | 89.4 |
| 106 | E | Rest | 92.1 | 95.1 | 97.0 | 90.2 |
| 107 | E | Work | 92.1 | 95.0 | 98.1 | 92.3 |
| 108 | B | Rest | 92.8 | 94.5 | 97.5 | 90.1 |
| 109 | B | Rest | 92.5 | 95.6 | 96.5 | 90.1 |
| 110 | B | Work | 92.6 | 95.6 | 97.5 | 91.3 |
| 111 | D | Rest | 94.1 | 93.8 | 97.9 | 90.4 |
| 112 | D | Rest | 90.6 | 91.9 | 97.4 | 90.1 |
| 113 | D | Work | 90.0 | 93.3 | 98.7 | 92.3 |
| 114 | E | Rest | 91.6 | 93.0 | 98.1 | 90.0 |
| 115 | E | Rest | 94.6 | 95.4 | 98.2 | 91.0 |
| 116 | E | Work | 93.8 | 95.4 | 98.4 | 91.9 |
| 117 | B | Rest | 93.0 | 95.6 | 98.2 | 91.1 |
| 118 | B | Rest | 93.4 | 95.2 | 98.2 | 90.9 |
| 119 | B | Work | 93.0 | 95.8 | 98.2 | 91.9 |
| 120 | D | Rest | 93.0 | 94.5 | 97.7 | 90.8 |
| 121 | D | Rest | 93.2 | 97.1 | 98.2 | 92.0 |
| 122 | D | Work | 91.0 | 95.2 | 98.7 | 93.0 |
| Average, rest experiments: | | | | | | |
| | | A, 6 experiments | 94.6 | 97.0 | 96.6 | 91.2 |
| | | B, 12 experiments | 93.5 | 95.6 | 97.5 | 90.5 |
| | | C, 3 experiments | 94.7 | 96.0 | 96.8 | 90.0 |
| | | D, 6 experiments | 91.8 | 92.8 | 97.9 | 90.4 |
| | | E, 4 experiments | 92.8 | 94.8 | 97.4 | 90.2 |
| | | Average, 31 experiments | 93.4 | 95.3 | 97.3 | 90.5 |
| Average, work experiments: | | | | | | |
| | | A, 3 experiments | 95.4 | 97.1 | 97.9 | 92.4 |
| | | B, 6 experiments | 93.3 | 95.2 | 98.1 | 91.5 |
| | | C, 2 experiments | 92.9 | 95.8 | 97.4 | 91.6 |
| | | D, 3 experiments | 90.3 | 93.9 | 98.8 | 92.6 |
| | | E, 2 experiments | 93.0 | 95.2 | 98.3 | 92.1 |
| | | Average, 16 experiments | 93.0 | 95.4 | 98.2 | 92.0 |
| | | Average all (47) experiments | 93.3 | 95.3 | 97.6 | 91.0 |

The figures at the end of the table show the average digestibility of the diet for each individual subject, both in the rest experiments and in the work experiments. It is interesting to note the very small differences in the digestibility of the food shown by the different sub-

jects. Individuality appears to have much less effect upon the results than might be expected. As a rule, the protein of the diet in the experiments of the first year seems to have been uniformly more completely digestible than in the experiments of the second year. Individual variations in the digestibility of the fat were even smaller than in the case of the protein, while there was comparatively little difference in the digestibility of the carbohydrates and in the energy of the digested food, either by different individuals or with different diets. The averages also show the digestibility of the food in the rest experiments and the work experiments. There was remarkably little variation in the proportion of nutrients digested during the rest periods as compared with the work periods. The average of 31 rest experiments shows 93.4 per cent of the protein, 95.3 per cent of the fat, 97.3 per cent of the carbohydrates, and 90.5 per cent of the energy of the food actually digestible, as compared with 93, 95.4, 98.2, and 92 per cent, respectively, in 16 work experiments with the same subjects. In other words, as far as these 47 experiments show, the variation in the digestibility of the nutrients of the diet due to differences in bodily activity or individual peculiarities were much less than the range of variation under uniform conditions. That there should be so small variations under different conditions of bodily activity and with different individuals is strong evidence that the average results of any considerable number of similar digestion experiments may be taken as actually representing the digestibility of the different nutrients in a given diet, and that such averages may be used in calculations. These experiments indicate that muscular work, even if quite severe, had no effect on the thoroughness with which a simple diet was digested. They do not, however, necessarily give an accurate measure of the digestibility of the same nutrients when furnished by different food materials or by the same materials in different proportions. In general, it may be said that the variations in digestibility are more marked in the case of protein than with other nutrients. Apparently the animal protein is more completely digestible than that of vegetable origin, and as a rule the larger the proportion of protein from animal foods in a diet the greater the proportion available for use in the body. Of course the data here given are too limited to permit of definite conclusions. They must be considered in connection with many other data of the same sort and in connection with figures for the digestibility of the different nutrients in single food materials or groups of similar food materials before final conclusions can be drawn.

## THE METABOLISM OF NITROGEN.

Nitrogen metabolism is affected by a considerable number of factors which these experiments can not take into account, and which are indeed little understood. The body requires protein and energy for

sustenance and for the production of muscular work. If we assume that in experiments with a grown man the demand for sustenance is the same in the rest as in the work period, the amount of nitrogen metabolized in the work, as compared with the rest period, will be influenced mainly, if not entirely, by (1) the increased demand for muscular activity and (2) the supply of available material for the repairing of tissue and yielding of energy. The increased demand is believed to depend upon the increase of not only the external (and internal) mechanical work of the muscles, but also upon the nervous effort involved, which appears to be, to a large extent, inversely proportional to the experience and skill of the subject in the performance of the work. The supply of available material includes not only the available nutrients of the ingested food, but also the store of material in the body. Thus it is easy to conceive that if the body of the man under experiment has no especially large store of protein, and the supply of fuel material during the work is increased, there may be no increase of nitrogen excretion during the work experiment, and that this may be the case whether all the fuel comes from the food or body fat is used for part of it. But if the store of protein in the body is large, or if there be not sufficient fuel available in the food, or food plus body fat, the metabolism and excretion of nitrogen in the work experiment may be much larger than in the rest experiment.

The elimination of nitrogen in the urine is usually taken as a measure of the metabolism of nitrogen in the body during a given period. It is, however, important to distinguish between metabolism and elimination of nitrogen. Under the term metabolism is properly included all changes of nitrogenous compounds, both constructive (anabolic) and destructive (catabolic). It has here been used chiefly in the latter sense, and includes all changes which the complex nitrogenous compounds of the food and tissue undergo before the nitrogen is finally excreted as urea and kindred compounds. Successive steps in the catabolism of protein during muscular work may not all take place during the performance of that work, and the final elimination of the nitrogen may lag still further behind the first steps of metabolism. It was in hopes of obtaining some light upon the duration of this lag that the nitrogen in the urine was determined in portions corresponding to six-hour intervals during the working periods in these experiments. However, the data obtained and reported in detail in the preceding pages showed no regular variation, and therefore throw little light upon this subject.

The results of the determinations of the balance of income and outgo of nitrogen in the experiments are briefly summarized in Table 58. As it was believed the effects of muscular work would be most apparent by comparing the periods in which the basal diet was practically the same, the only changes being in the amount of muscular work done and the energy added to the diet to (theoretically) provide for

this work, the table includes only the results of the second rest period and the third or work period in each experiment. The table shows whether the subject rested or worked, the income and outgo of nitrogen, and the total and available energy in the experimental periods. The calculated amount of work, which, though considerable, was probably much less than the actual amount, is also shown, together with its heat equivalent.

TABLE 58.—*Comparison of nitrogen balance in the second rest and in the work periods.*

[Quantities per day.]

| Number of metabolism experiment. | Number of digestion experiment. | Character of experiment. | Subject. | Average gain (+) or loss (−) in body weight. | Nitrogen. | | | Available energy in food. | Average heat equivalent of work done. |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Available in food. | Eliminated in urine. | Gain (+) or loss (−). | | |
| | | | | *Kgs.* | *Grams.* | *Grams.* | *Grams.* | *Calories.* | *Calories.* |
| 1 | 54 | Rest | A | −0.14 | 16.81 | 15.48 | +1.33 | 2,818 | ..... |
| | 55 | Work | A | 0 | 20.00 | 16.29 | +3.71 | 3,711 | 56 |
| 2 | 57 | Rest | B | − .32 | 21.84 | 20.52 | +1.32 | 3,088 | ..... |
| | 58 | Work | B | − .63 | 24.54 | 20.41 | +4.13 | 3,980 | 43 |
| 3 | 60 | Rest | C | − .54 | 16.54 | 15.00 | +1.54 | 2,300 | ..... |
| | 61 | Work | C | − .63 | 19.19 | 15.20 | +4.09 | 3,051 | 55 |
| 4 | 63 | Rest | A | − .32 | 13.90 | 13.27 | + .63 | 2,406 | ..... |
| | 64 | Work | A | − .05 | 16.14 | 15.36 | + .78 | 3,265 | 96 |
| 5 | 66 | Rest | B | 0 | 17.93 | 18.41 | − .48 | 3,079 | ..... |
| | 67 | Work | B | 0 | 18.74 | 17.81 | + .93 | 3,586 | 66 |
| 6 | 68 | Rest | C | − .27 | 12.70 | 13.11 | − .41 | 2,193 | ..... |
| | 69 | Work | C | − .09 | 13.72 | 13.08 | + .64 | 2,875 | 95 |
| 7 | 71 | Rest | A | − .14 | 21.68 | 21.35 | + .33 | 3,199 | ..... |
| | 72 | Work | A | + .23 | 22.34 | 21.48 | + .86 | 3,760 | 110 |
| 8 | 74 | Rest | B | 0 | 24.88 | 24.01 | + .87 | 3,540 | ..... |
| | 75 | Work | B | + .45 | 25.38 | 23.01 | +2.37 | 4,010 | 110 |
| 9 | 100 | Rest | B | − .15 | 19.01 | 22.13 | −3.12 | 2,900 | ..... |
| | 101 | Work | B | 0 | 19.06 | 17.85 | +1.21 | 3,532 | 127 |
| 10 | 103 | Rest | D | − .07 | 10.13 | 11.40 | −1.27 | 1,917 | ..... |
| | 104 | Work | D | − .06 | 10.12 | 9.71 | + .41 | 2,520 | 132 |
| 11 | 106 | Rest | E | − .14 | 10.66 | 11.70 | −1.04 | 1,889 | ..... |
| | 107 | Work | E | − .05 | 10.59 | 10.93 | − .34 | 2,454 | 147 |
| 12 | 109 | Rest | B | 0 | 20.52 | 21.39 | − .87 | 3,141 | ..... |
| | 110 | Work | B | 0 | 20.24 | 19.93 | + .31 | 3,600 | 147 |
| 13 | 112 | Rest | D | − .12 | 11.40 | 11.49 | − .09 | 2,067 | ..... |
| | 113 | Work | D | − .15 | 10.94 | 11.08 | − .14 | 2,565 | 148 |
| 14 | 115 | Rest | E | − .23 | 17.58 | 16.87 | + .71 | 2,450 | ..... |
| | 116 | Work | E | 0 | 17.24 | 18.34 | −1.10 | 3,020 | 138 |
| 15 | 118 | Rest | B | − .45 | 18.76 | 18.97 | − .21 | 2,650 | ..... |
| | 119 | Work | B | 0 | 18.49 | 18.76 | − .27 | 3,240 | 139 |
| 16 | 121 | Rest | D | − .22 | 11.77 | 11.48 | + .29 | 2,002 | ..... |
| | 122 | Work | D | − .45 | 11.38 | 10.81 | + .57 | 2,557 | 130 |

In the experiments included in the table the muscular work and the supply of fuel ingredients (total energy) were increased together. The apparent metabolism of nitrogen remained nearly the same. The excretion in the urine decreased rather than increased with the increase of muscular work. Apparently the extra muscular work was done entirely at the expense of the extra energy supplied by nonnitrogenous nutrients without any increased wear and tear of the machine. It is possible that more nitrogen was metabolized in the body during the work than during the rest period but was not excreted in the urine until after the experiment ended, but it is believed that the quantity of nitrogen so retained was not large enough to affect the deductions drawn, as no regular nitrogen lag was observed. It has already been pointed out that it is not impossible nor even improbable that nitrog-

enous cleavage products may remain in the body for a considerable period after the muscular work has been performed. In some of the work experiments described above the urine was collected for a day after the close of the work period, and, as a rule, showed an increase of nitrogen elimination over that of the days in which work was performed. This would suggest that more nitrogen was metabolized during the work period but that the excess was not carried away by the urine until later. Such nitrogen lag has been observed by other investigators.[1] Inasmuch, however, as some of the work periods in these experiments continued six days it seems hardly probable that this lag influenced to any marked degree the results here reported.

Of course it is also possible that there may have been an appreciable elimination of nitrogen through the skin. It is well known that a small amount of urea may be thus eliminated during active perspiration. In experiments[2] carried on by Atwater and associates at Middletown, Conn., the elimination in this way has not been found to exceed 0.4 gram of nitrogen per day, and this only in the case of very active work and profuse perspiration. It seems hardly probable, therefore, that there could have been any marked loss of nitrogen in this way.

The methods employed for estimating muscular work are not satisfactory as regards total amounts. They are believed, however, to be fairly satisfactory for the purpose intended since they show relatively the amount of work in different experiments and show further that a considerable amount of work was performed. As already pointed out, one form of apparatus used to measure the external muscular work was a friction machine, which was not of such nature as to insure a high degree of efficiency and the increased muscular effort during the work period was probably largely in excess of that indicated by the machine. In fact it has been found that a machine turned by a crank or windlass and operated by the arms is much less efficient than one on which the subject can utilize the muscles of the legs, as a bicycle or a treadmill. The amount of work actually measured was considerably larger in some experiments than in others. In all cases the actual amount must have been greatly in excess of that measured.

In experiments of this sort there is no satisfactory way of determining or calculating whether or not the subject is losing or storing body matter. The change in body weight between the beginning and the end of the periods, unless very marked in amount, can not be taken as a measure of the gain or loss of body material. There is uncertainty concerning the total amount of water within the system at one time as compared with another, and there is also no reason to believe that the amount of solid material within the alimentary canal is the same at

[1] U. S. Dept. Agr., Office of Experiment Stations Bul. 45, pp. 129–135.

[2] U. S. Dept. Agr., Office of Experiment Stations Bul. 69, and unpublished data

corresponding times on successive days even if the diet is uniform. In other words, there may be an appreciable change in body weight due to unusually small or large elimination of solid or liquid excretory products on a given day.

## GENERAL SUMMARY.

Sixteen experiments are reported in the previous pages, which are the first of a series now being carried on for the purpose of studying the effect of muscular work upon the digestibility of a simple mixed diet and the metabolism of nitrogen. Each experiment consisted of one or more rest periods followed by a work period. The muscular work performed during the work period of the experiments carried on during 1898 was not at all severe. There was, moreover, a slight increase of nitrogen in the diet during the work period in addition to a large increase of energy from additional fats and carbohydrates in the ration (in some cases as much as 1,000 calories per day). It was found that the digestibility of the diet was not appreciably affected under these conditions. As regards the income and outgo of nitrogen, there was almost invariably a gain of nitrogen during the period of work which amounted to as much as 5 grams per day at times. Allowing for the slightly increased amount of nitrogen in the daily diet during this period, as compared with the preceding rest period, there was at times a relative gain and at times a relative loss of nitrogen. In the experiments made during the year 1899, the energy in the diet during the period of muscular activity was increased by about 500 calories per day while the nitrogen remained practically the same as during the preceding rest period. The calculated energy required for the measured muscular work ranged from 127 to 147 calories and averaged 139 per day. The digestibility of the diet was again uninfluenced by muscular work. A study of the nitrogen balance shows that in the majority of cases if there was a gain during the rest period it was increased during the work period and if there was a loss it was diminished. In other words, comparing the elimination of nitrogen in the urine during the periods of little muscular activity and normal diet with that during periods of increased activity and a diet furnishing energy largely in excess of the heat equivalent of the measured work performed, there seems to be a slight decrease under the latter condition. This is true even when we consider the possibilities of a small loss of nitrogen in the perspiration and a lag of considerable duration between the breaking down of nitrogenous material within the body and the excretion of nitrogen in the urine.

Experiments now being made to study the effects of work upon nitrogen metabolism under different conditions as regards the supply of protein and energy will, it is hoped, throw additional light upon this question.

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### SEPARATES.

Food and Diet. By W. O. Atwater. Reprinted from Yearbook of Department of Agriculture for 1894. Pp. 44.

Foods for Man. Reprinted from Yearbook of Department of Agriculture for 1897. Pp. 7.

Some Results of Dietary Studies in the United States. By A. P. Bryant. Reprinted from Yearbook of Department of Agriculture for 1898. Pp. 14.

Development of the Nutrition Investigations of the Department of Agriculture. By A. C. True and R. D. Milner. Reprinted from Yearbook of Department of Agriculture for 1899. Pp. 16.